SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

INVESTIGATIONS,

CHEMICAL AND PHYSIOLOGICAL,

RELATIVE TO CERTAIN

AMERICAN VERTEBRATA.

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INTRODUCTION.

THE investigations recorded in the following pages were for the most part conducted in Liberty County, Georgia, where the author had opportunities of obtaining fresh specimens of vertebrata, living and dead, seldom enjoyed by observers. The researches, however, were necessarily attended with great labor and many embarrassments consequent upon the peculiar habits of the animals and the extreme difficulty of access, and miasmatic condition of their localities.

Owing to the extent and complexity of the topics discussed in this Memoir, the results presented must necessarily be very imperfect; and, in fact, are to be considered merely as contributions to science, to be continued and completed hereafter by the author, or by others who may have proper opportunities for so doing.

Whatever may be thought of the deductions and generalizations of the author, he is confident that the experiments which he has presented, and which have been made at so great an expense of time and labor, and which have involved so many sacrifices, will not be considered without value in throwing some light upon the important questions to which they pertain.

CHAPTER I.

METHOD OF ANALYZING THE BLOOD.[1]

The blood is a highly complex fluid, and, in investigations upon cold-blooded animals, it is impossible, in most instances, to determine all, or even a majority of its constituents, owing to the small amount (often not more than 100 grains) which can, even with the greatest care, be obtained from each individual.

As little or nothing has been done in the study of the fluids of these animals, it was necessary first to determine the most important constituents. The following is a brief statement of the method which I employ to determine the

Water.
Solid Constituents of Blood.
Solid Constituents of Serum.
Moist Blood-corpuscles.
Solid Constituents of Moist Blood-corpuscles.
Water of Moist Blood-corpuscles.
Liquor Sanguinis.
Solid Constituents of Liquor Sanguinis.
Water of Liquor Sanguinis.
Albumen and Extractive Matters.
Fibrin.
Fixed Saline Constituents.

(*a.*) Receive into a porcelain capsule, capable of containing about f℥ss (the weight of which had been previously carefully ascertained and noted), from twenty-five to fifty grains of blood.

(*b.*) Fill a 100 grain sp. gr. bottle with blood, if the animal be large enough to yield several hundred grains of blood.

(*c.*) Receive the remainder of the blood into a porcelain capsule (weight previously ascertained) capable of containing about 500 grains of blood.

In the majority of reptiles and small birds and mammals, the blood will have been exhausted after the filling of the last vessel.

Treatment of the Portion (*a*).

Carefully ascertain the weight of the capsule with its blood, with a delicate balance, and subtracting from this the weight of the capsule, we have remaining the weight of the blood.

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[1] The character of the Smithsonian Contributions does not permit of an extended discussion of the various methods of analysis employed by different physiological chemists. Those who wish to investigate this subject for themselves, will find much useful information in Simon's Chemistry of Man, p. 142, Philadelphia, 1846; Lehmann's Physiological Chemistry, translated by G. E. Day, and edited by Prof. R. Rogers, Vol. I, pp. 541–648, Philadelphia, 1855; Bowman's Medical Chemistry, pp. 145–194, Philadelphia, 1850.

Place it upon a chloride of calcium bath, and subject it to a temperature of from 220° to 230° F. until it ceases to lose weight, on being weighed at intervals of half an hour or an hour, the outside of the capsule being wiped clean and dry each time. Subtracting the weight of the porcelain capsule from the last weight, we obtain the *amount of solid matter in the portion of blood evaporated,* and subtracting the solid matter from the amount of blood employed, we ascertain the *amount of water.*

To ascertain the amount of *solid matter in* 1000 *parts of blood,* we use the following proportion:—

$$\left.\begin{matrix}\text{Weight of}\\ \text{blood evaporated}\end{matrix}\right\} : \left\{\begin{matrix}\text{Weight of}\\ \text{dry residue}\end{matrix}\right\} :: 1000 : \left\{\begin{matrix}\text{Proportion of solid matter}\\ \text{in 1000 parts of the blood.}\end{matrix}\right.$$

Having ascertained the solid matter in 1000 parts of blood, the amount of water may be determined by simply subtracting the solid matter from 1000.

Next, incinerate the solid residue in a porcelain or platinum[1] crucible, until all the carbonaceous portion is consumed, and a light-red or yellow ash remains behind. A high heat and much care are indispensable in this tedious process.

Another method, recommended by Dr. R. E. Rogers, Professor of Chemistry in the University of Pennsylvania, is to treat the dried residue with nitric acid, and, gradually boiling down, incinerate. The organic matters readily dissolve in the hot nitric acid, and pass off in the form of gases.

The proportion of *fixed saline matter* in 1000 parts of blood may be calculated in the following manner:—

$$\left.\begin{matrix}\text{Weight of}\\ \text{blood evaporated}\end{matrix}\right\} : \left\{\begin{matrix}\text{Weight of ash}\\ \text{after incineration}\end{matrix}\right\} :: 1000 : \left\{\begin{matrix}\text{Proportion of fixid saline matter}\\ \text{in 1000 parts of blood.}\end{matrix}\right.$$

From this first portion of blood, we have now obtained—

Water in 1000 parts of blood.
Solid matter in 1000 parts of blood.
Fixed saline matter in 1000 parts of blood.

Treatment of the Portion (*b*).

Determine accurately, with the balance, the specific gravity of the blood. This should be done immediately after the porcelain capsule containing the blood is placed upon the chloride of calcium bath.

Treatment of the Portion (*c*).

Ascertain the weight of the porcelain capsule and the blood which it contains, and, subtracting the weight of the capsule, we have remaining that of the blood. Set it aside until the blood is completely coagulated, and the serum separated from the clot. The length of time required for this varies according to circumstances and the character of the animal.

Ascertain the specific gravity of the serum in the 100 grain sp. gr. bottle.

Pour into a porcelain capsule (weight previously noted) from ten to fifty grains

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[1] For general purposes, a crucible of porcelain is to be preferred to one of platinum.

of serum, and evaporate upon the chloride of calcium bath until it ceases to lose weight. The *water, solid residue,* and *fixed saline constituents in* 1000 *parts of serum* may be ascertained in a manner exactly similar to that by which these ingredients were determined in 1000 parts of blood.

From the numbers now obtained, the proportion of *solid matters of the serum of* 1000 *parts of the blood* may be calculated in the following manner: Knowing the quantity of water in 1000 parts of blood, and assuming that this water exists wholly in the form of serum; knowing also the amount of water and solid matter contained in a given portion of serum; we may, from the quantity of water in the blood, estimate the quantity of solids held in solution in the serum, thus:—

Weight of water in the quantity of serum employed	:	Weight of solid matter in the quantity of serum employed	: :	Water in 1000 parts of the blood		Solids of serum in 1000 parts of the blood.

This is not absolutely correct, and all physiological chemists have failed to ascertain, with absolute accuracy, the amount of solid matter in the serum of 1000 parts of blood. The error,[1] in the present state of our knowledge, is unavoidable.

The clot which remains after the removal of the serum, is next cut into thin slices, and inclosed in a muslin bag, and carefully washed under a stream of water until the fibrin remains in the bag free from serum and blood-corpuscles, and becomes almost colorless.

Another method of obtaining the fibrin, is to receive into a small glass bottle (capable of containing from two to four fluidounces) a portion of blood, and then dropping in some dozen small strips of lead, and closing with the stopper, agitate and shake until the fibrin coagulates around the lead strips. Two strong objections lie against the employment of this method in investigations upon cold-blooded animals. 1st. Their blood, in most cases, cannot be obtained in sufficient quantities. 2d. The fibrin, in most individuals, is so soft, that it will not coagulate around the lead strips. Neither of these methods is strictly correct. A portion of the fibrin is necessarily lost during the process of washing, and that which remains always contains colorless blood-cells and remains of colored cells.

The fibrin thus obtained is placed in a small evaporating dish, and dried upon the chloride of calcium bath, until it ceases to lose weight. If we wish still greater accuracy, the fatty and extractive matter may be removed by alcohol and ether, and, after complete drying, its weight is ascertained, and it is finally incinerated and the weight of the ash deducted. The proportion of fibrin in 1000 parts of blood may be determined by a simple proportion.

The amount of albumen and extractive matters in 1000 parts of blood may be determined by subtracting the saline matter of the serum of 1000 parts of blood, from the solid residue of the same.

From the third portion of blood (*c*), we have determined the following constituents:—

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[1] Several physiological chemists have attempted, without success, to avoid this source of error, by determining absolutely the amount of blood-corpuscles.

Water in 1000 parts of serum.
Solid constituents in 1000 parts of serum.
Solid constituents in serum of 1000 parts of blood.
Albumen and extractive matters.
Fixed saline constituents in 1000 parts of serum.
Fibrin in 1000 parts of blood.

We have now sufficient data from which to calculate the *dried blood-corpuscles, moist blood-corpuscles,* and *liquor sanguinis.*

To ascertain the weight of the *dried blood-corpuscles,* add together the weights of the fibrin and the solids of the serum contained in 1000 parts of blood, and deducting the sum of them from the weight of the entire solid matter, which consists of fibrin, solids of the serum, and blood-corpuscles; the difference will represent the proportion of the latter in 1000 parts of blood.

Another method is founded upon the fact, that a solution of the sulphate of soda possesses the property of rendering the blood-corpuscles capable of being retained upon a filter. This method was first applied by Figuier, and afterwards improved by Dumas and Höfle. Defibrinated blood is treated with eight times its volume of a concentrated solution of Glauber's salts, and filtered, the residue on the filter is rinsed with the same solution, a stream of oxygen is passed through the mass of blood-cells on the filter, and, finally, the mass of blood-cells is either coagulated with hot water, upon the filter, or washed off into tepid water and coagulated by boiling.

This method is not to be depended upon in practice, because some of the blood-corpuscles always pass through the filter, and it is impossible to determine whether all the serum is actually separated in this manner, and also because the solution of the sulphate of soda passes into the corpuscles by endosmosis, whilst the organic constituents of the corpuscles pass out.

F. Simon's method of finding the quantity of the blood-corpuscles directly, is not only tedious, but also wanting in accuracy.

C. Schmidt, to whose intelligence and indefatigable researches physiological chemistry is indebted for many brilliant discoveries, first attempted to determine the relation of the moist blood-cells to the intercellular fluid, or liquor sanguinis. He found that 4 is the constant factor by which we may calculate the moist blood-cells from the dry blood-corpuscles. If we multiply the number of dry blood-corpuscles by 4, we obtain the quantity of fresh blood-cells. Subtracting these from 1000, we have remaining the amount of liquor sanguinis in 1000 parts of blood.

Having briefly described the method by which these important constituents are obtained, we will next state the manner in which the results are exhibited. The constituents of 1000 parts of blood are always presented in two lights.

1st. The fixed saline matter of the dried blood-corpuscles is subtracted from their weight, and we have remaining the dried organic matter of the blood-corpuscles in 1000 parts of blood. In like manner, the fixed saline constituents of the serum of 1000 parts of blood are subtracted from the solid matter of the serum of 1000 parts of blood, and we have remaining the dried organic portion of the albumen and extractive matter. It is evident that, if the analysis has been properly

conducted, the sum of the water, dried organic matter of the blood-corpuscles, dried organic matter of the albumen and extractive matters, the fibrin, and fixed saline constituents will equal 1000.

2d. The relation of the moist blood-cells to the intercellular fluid, or liquor sanguinis, in 1000 parts of blood is represented separately.

The exhibition of the constituents of the blood in two different lights, enables us to comprehend more correctly its true constitution, and compare more readily the blood of different animals.

Without stopping to consider the various steps of caution and accuracy which would naturally suggest themselves to every careful observer, we will simply state that the balance used in all these investigations was reliable, and would, with proper care, indicate $\frac{1}{1000}$th of a Troy grain.

CHAPTER II.

BLOOD OF VERTEBRATE ANIMALS IN ITS NORMAL CONDITION.

Blood of Fishes.

1. *Trygon sabina*, Les. (female). Stingray. Aug. 14, 1855.

The appearance of the left uterus of this Ray, indicated that it had been delivered of young ones only a short time before its capture.

The appearance of the viscera and impregnated uterus of one of these fishes is represented in Fig. 19.

The portion of blood first drawn coagulated, in a few moments, into a dense, firm clot, which, in the course of an hour, commenced to dissolve, and in two hours, entirely disappeared. Another portion of blood, drawn subsequently, coagulated imperfectly, allowing the majority of the blood-corpuscles to settle to the bottom of the vessel, and, in the course of half an hour, the fibrin was completely dissolved.

Solid constituents in 1000 parts of blood	115.80

1000 parts of blood contained—

Water	884.20
Solid organic constituents	101.10
Fixed saline constituents	14.70

2. *Zygæna malleus*, Val. Hammerhead Shark. Sept. 10.

The blood coagulated imperfectly, allowing the blood-corpuscles to settle, and the fibrin, in the course of a few hours, was dissolved.

Solid constituents in 1000 parts of blood	138.86
" " " serum	70.96
" " in serum of 1000 parts of blood	65.50
Water in 1000 parts of blood	861.14
" " serum	929.31

1000 parts of blood contained—

Water	861.14
Blood-corpuscles (dried organic constituents)	70.24
Albumen, extractive and fatty matters (dried organic constituents)	60.24
Fibrin	Unstable, coagulating imperfectly, and readily dissolving
Fixed saline constituents	8.38
Fixed saline constituents of blood-corpuscles of 1000 parts of blood	5.26
" " solid matter of serum of 1000 parts of blood	3.12

1000 parts of blood contained—

Moist blood-corpuscles	293.44	Water	220.08
		Organic constituents	68.10
		Fixed saline constituents	5.26
Liquor sanguinis	706.56	Water	641.06
		Organic constituents	62.38
		Fixed saline constituents	3.12

3. *Lepisosteus osseus*, Linnæus. Salt-water Garfish.[1] Aug. 13.

In the southern part of Georgia, we have two species called garfish. The largest inhabits the salt-water rivers and Atlantic ocean, and the other our swamps and fresh-water canals of the rice-fields. The head and jaws of the former are much longer and more slender than those of the latter.

The viscera of the fresh-water species are represented in Fig. 11.

The blood coagulated in an imperfect manner, and, in the course of an hour, the fibrin dissolved and the blood-corpuscles settled to the bottom of the vessel, leaving the clear serum above. In one of the vessels, the blood scarcely coagulated, and the fibrin dissolved in twenty minutes.

It is characteristic of the blood of Fishes, that the arrangement of the atoms of albumen, so as to form fibrin, is very unstable. This instability and imperfection of the fibrin is indicative of a feeble state of the vital force, and, as a necessary consequence, of an imperfect condition of the organs which elaborate the blood.

Solid constituents in 1000 parts of blood	113.30
" " " serum	59.45
" " in serum of 1000 parts of blood	56.05
Water in 1000 parts of blood	886.70
" " serum	940.55

1000 parts of blood contained—

Moist blood-corpuscles	229.00	Water	171.75
		Solid constituents	57.25
Liquor sanguinis	771.00	Water	714.95
		Solid constituents	56.05

1000 parts of blood contained—

Water	886.70
Blood-corpuscles (dried organic constituents)	52.11
Albumen, extractive and fatty matters	50.92
Fibrin	Unstable, being readily dissolved and converted into albumen
Fixed saline constituents	10.27

Blood of Batrachians.

4. *Rana catesboeana*, Shaw. Bullfrog. July 30.

The stomach of this Batrachian contained several Crawfish (*Astacus Bartoni*), and a long slender Grass Snake (*Tropidonotus ordinatus*) about three feet in length. It

[1] This name, as well as some others, is used provisionally until a more critical examination shall have settled its precise synonomy.

had also swallowed, apparently along with the snake, a bunch of shank grass. Although this large frog had been captured for more than seventeen hours, and retained alive in water, the exterior part only of the body of the serpent showed the action of the gastric juice. The stomach contained none of the chyme so often referred to by writers on digestion. We have repeatedly examined the stomachs of Alligators, other Reptiles, and Fishes, and warm-blooded animals, during digestion, and we have never in any instance found a large amount of fluid either in the stomach or intestines. The products of digestion are absorbed almost as fast as they are formed.

The portions of blood first drawn coagulated more slowly than those drawn last. After the blood had flowed for a few moments, it coagulated as soon as it left the wound. The coagulum formed in the different portions of blood embraced most of the blood-corpuscles, and yielded clear serum.

In every instance, after standing for a few hours, the fibrin entirely disappeared, the clot was dissolved, and the blood-corpuscles set free.

The coagulum formed in the blood of the frog was firmer than that of Fishes, but not so firm as that of Serpents and Terrapins and the higher orders of vertebrate animals.

The color of the blood was purplish-red, intermediate between that of venous and arterial blood in Birds and Mammals.

The serum was of a light yellow color.

The strength of the Frog was exhausted more rapidly by the loss of blood than that of Serpents and Chelonians.

Solid constituents in 1000 parts of blood	167.49
" " " serum	61.93
" " in serum of 1000 parts of blood	54.96
Water in 1000 parts of blood	832.51
" " serum	938.07

1000 parts of blood contained—

Water	832.51
Blood-corpuscles (dried organic constituents)	108.68
Albumen, extractive and fatty matters	53.03
Fibrin	Unstable, readily convertible into albumen
Fixed saline constituents	5.78

1000 parts of blood contained—

Moist blood-corpuscles	450.12	Water	337.59
		Solid constituents	112.53
Liquor sanguinis	549.88	Water	494.92
		Solid constituents	54.96

Blood of Ophidians.

5. *Heterodon platyrhinos*, Latreille (female). Hog-nose Viper. June 8.

The alimentary canal was completely empty, and the rectum contained fæcal matter in small amount. All the blood that could be obtained with the greatest care was $33\frac{4}{10}$ grains.

From these facts, it is probable that the serpent had been without food for some days, and perhaps weeks. It had been captured only three days previous to the analysis.

From the small amount of blood yielded by this animal, it was impossible to determine the amount of fibrin.

Solid constituents in 1000 parts of blood	166.76
" " " serum	62.50
" in serum of 1000 parts of blood	55.55
Water in 1000 parts of blood	833.24
" " serum	937.50

1000 parts of blood contained—

Water	833.24
Blood-corpuscles and fibrin	102.22
Albumen, fatty and extractive matter	51.07
Fixed saline constituents	13.47

1000 parts of blood contained—

Moist blood-corpuscles	444.84	Water	333.63
		Solid constituents	111.21
Liquor sanguinis	555.16	Water	499.61
		Solid constituents	55.55

6. *Heterodon niger*, Catesby (female). Black Viper. May 21.

This reptile had been kept without food for more than two weeks.

Solid constituents in 1000 parts of blood	139.43
" " " serum	74.89
" in serum of 1000 parts of blood	69.67
Water in 1000 parts of blood	860.57
" " serum	925.11

1000 parts of blood contained—

Water	860.57
Blood-corpuscles (dried organic constituents)	64.07
Albumen, fatty and extractive matter	66.16
Fibrin	2.16
Fixed saline constituents	7.04

1000 parts of blood contained—

Moist blood-corpuscles	270.40	Water	202.80
		Solid constituents	67.60
Liquor sanguinis	729.60	Water	657.77
		Solid constituents	71.83
Amount of blood obtained			230 grains

7. *Psammophis flagelliformis*, Catesby (male). Coachwhip Snake. June 13.

This serpent is active and strong, and its movements, like those of the Black Snake (*Coluber constricttor*), are characterized by great swiftness. It had been confined without food for one day. Amount of blood obtained, 480 grains.

Specific gravity of its blood	1036
Solid constituents in 1000 parts of blood	181.70
" " " serum	65.78
" in serum of 1000 parts of blood	57.62
Water in 1000 parts of blood	818.30
" " serum	934.22

1000 parts of blood contained—

Water	818.30
Blood-corpuscles (dried organic constituents)	118.34
Albumen, fatty and extractive matter	55.91
Fibrin	1.88
Fixed saline constituents	5.57

1000 parts of blood contained—

Moist blood-corpuscles	488.80	Water	366.60
		Solid constituents	122.20
Liquor sanguinis	511.20	Water	451.70
		Solid constituents	59.50

8. *Coluber constrictor,* Linnæus (male). Black Snake. May 17.

This snake had been kept without food for ten days.

This is one of the swiftest and strongest of all our North American Ophidians. I have seen it attack the Rattlesnake, and sever the head almost completely from the body. In its habits, food, and swift motions, it resembles very much the Coach-whip Snake (*Psammophis flagelliformis*).

Amount of blood obtained	350 grains
Solid constituents in 1000 parts of blood	211.37
" " " serum	101.42
" in serum of 1000 parts of blood	89.01
Water in 1000 parts of blood	788.63
" " serum	898.58

1000 parts of blood contained—

Water	788.63
Blood-corpuscles (dried organic constituents)	112.22
Albumen, fatty and extractive matter	85.32
Fibrin	5.06
Fixed saline constituents	8.77

1000 parts of blood contained—

Moist blood-corpuscles	469.20	Water	351.90
		Solid constituents	117.30
Liquor sanguinis	530.80	Water	436.73
		Solid constituents	94.07

Blood of Saurians.

9. *Alligator Mississippiensis,* Daudin (female). Alligator. April 30.

The blood was abstracted a short time after the animal was shot in a small stream.

The reptile was remarkably fleshy, and the abdominal cavity, especially about the kidneys, was lined with fat.

The blood was much more abundant than in a male Alligator, which was captured in the same locality in the month of March, and kept without food or drink for three weeks. It also did not coagulate so rapidly.

From the starved Alligator, not more than three fluidounces of blood, with care, could be collected, the veins and arteries of the neck having been opened whilst the animal was living. Although the subject of experiment had been shot for half an hour, still the blood flowed from the jugular veins and carotid arteries in rapid streams, and more than ten fluidounces were readily obtained.

The hole of this Alligator was in the bank of a small stream, which flowed through an extensive salt marsh, abounding with small Fishes and Crustaceans. This reptile, therefore, was abundantly supplied with food.

Specific gravity of defibrinated blood	1046
Solid constituents in 1000 parts of blood	176.14
" " " serum	90.80
" in serum of 1000 parts of blood	82.05
Water in 1000 parts of blood	823.86
" " serum	909.20

1000 parts of blood contained—

Water	823.86
Blood-corpuscles (dried organic constituents)	86.39
Albumen	63.75
Fibrin	3.07
Water and alcohol extractive	9.26
Fatty matter	5.02
Fixed saline constituents	8.65

1000 parts of blood contained—

Moist blood-corpuscles	364.08	Water	273.06
		Solid constituents	91.02
Liquor sanguinis	635.92	Water	550.80
		Solid constituents	85.12

Blood of Chelonians.

10. *Chelonia caretta*, Linnæus. Loggerhead Turtle. July 20.

The blood was examined two days after its capture. During this time, it was kept in a tub of salt water, and supplied with small Fishes.

The blood first drawn coagulated more slowly than that drawn last.

Portions of the blood were placed in several vessels and allowed to coagulate; and, in every instance, the blood-corpuscles settled to the bottom of the vessel, leaving above a transparent clot.

When first abstracted, it was of a dark red color, not so black as venous, but much darker than the arterial blood of warm-blooded animals. This is readily explained when we consider that the venous and arterial blood is mixed in the ventricle of the heart.

The reaction of the blood was slightly alkaline.

Whilst taking the specific gravity of the serum, which had been separated from

the clot for several hours, another small clot separated in the specific gravity bottle, having the characteristic appearance of fibrin.

The cavity of the abdomen contained half a fluidounce of clear serous fluid, which coagulated upon standing.

Specific gravity of the blood	1032.5
" " serum	1014.8
Solid constituents in 1000 parts of blood	120.81
" " " serum	49.44
" in serum of 1000 parts of blood	45.82
Water in 1000 parts of blood	879.19
" " serum	950.56

1000 parts of blood contained—

Water	879.19
Blood-corpuscles (dried organic constituents)	69.99
Albumen, fatty and extractive matter	44.63
Fibrin	2.61
Fixed saline constituents	3.58

1000 parts of blood contained—

Moist blood-corpuscles	289.52	Water	217.14
		Solid constituents	72.38
Liquor sanguinis	710.48	Water	662.05
		Solid constituents	48.43

11. *Chelonura serpentina*, Linnæus (male). Snapping Turtle. July 16.

The viscera of this Chelonian are represented in Fig. 8.

This reptile had been captured four days, during the greater portion of which time it was placed in water and supplied with Purslain (*Portulacca oleracea*).

The portions of blood drawn first coagulated more slowly than those drawn last. We have found this phenomenon to occur with all animals whose blood coagulated sufficiently slow to admit of a comparison of the times of coagulation. It appears to be an effort of nature to arrest hemorrhages. The manner in which the albumen of the blood is converted into fibrin is unknown. From the rapidity of the change during bleeding, it appears to have some connection with the nervous system. Whether it be due to nervous influence, or the action of the capillaries upon the albumen, or the mutual reactions between the corpuscular floating glands of the blood, remains to be demonstrated.

The coagulum was small and inconsistent.

The great majority of the blood-corpuscles settled to the bottom of the vessel, and were not included in the clot. In these respects, the blood of the *Chelonura serpentina* resembled that of Fishes and Frogs.

The serum was of a light yellow color, and, when treated with sulphuric acid and gently heated, the characteristic musky odor of the animal was developed.

Specific gravity of the blood	1025.5
" " serum	1013.6
Amount of blood obtained	700 grains

Solid constituents in 1000 parts of blood	105.00
" " " serum	48.68
" in serum of 1000 parts of blood	45.80
Water in 1000 parts of blood	895.00
" " serum	951.32

1000 parts of blood contained—

Water	895.00
Blood-corpuscles (dried organic constituents)	56.37
Albumen, extractive and fatty matter	43.89
Fibrin	.35
Fixed saline constituents	4.39

1000 parts of blood contained—

Moist blood-corpuscles	235.40	Water	176.55
		Solid constituents	58.85
Liquor sanguinis	764.60	Water	718.45
		Solid constituents	46.15

12. *Emys Terrapin,* Schœpff (female). Salt-water Terrapin. July 3.
This terrapin had been captured twelve hours.

Specific gravity of its blood	1035.3
" " serum	1012.7

The serum was of a golden color, resembling that of the *Emys serrata* and *Emys reticulata.*

Amount of blood obtained, about	1000 grains
Solid constituents in 1000 parts of blood	154.72
" " " serum	43.83
" in serum of 1000 parts of blood	38.75
Water in 1000 parts of blood	845.28
" " serum	956.17

1000 parts of blood contained—

Water	845.28
Blood-corpuscles (dried organic constituents)	103.82
Albumen, fatty and extractive matter	36.01
Fibrin	4.15
Fixed saline constituents	10.74

1000 parts of blood contained—

Moist blood-corpuscles	447.28	Water	335.46
		Solid constituents	111.82
Liquor sanguinis	552.72	Water	509.82
		Solid constituents	42.90

13. *Emys reticulata,* Bosc. Chicken Tortoise. June 6.

This Chelonian was captured in a pine-barren, and kept without food or drink for thirty-six hours.

The portions of blood first drawn coagulated more slowly than those last drawn. This is universally the case with the blood of cold-blooded animals.

The serum was of a bright orange color.

The alimentary canal was empty as far as the colon. The rectum and colon contained the claws and shells of small crustaceans, and the seeds of berries.

Specific gravity of the blood	1034
Solid constituents in 1000 parts of blood	153.02
" " " serum	63.58
" in serum of 1000 parts of blood	57.51
Water in 1000 parts of blood	846.98
" " serum	936.42

1000 parts of blood contained—

Water	846.98
Blood-corpuscles (dried organic constituents)	88.01
Albumen, fatty and extractive matter	54.71
Fibrin	2.51
Fixed saline constituents	7.79

1000 parts of blood contained—

Moist blood-corpuscles	372.00	Water	279.00
		Solid constituents	93.00
Liquor sanguinis	628.00	Water	567.98
		Solid constituents	60.02

14. *Emys serrata*, Daudin (female). Yellow-bellied Terrapin. May 26.

This terrapin was taken in a swamp and kept out of the water, without food, for three and a half days.

The first portion of blood drawn was placed in a small beaker glass, and coagulated so slowly that the blood-corpuscles sank to the bottom of the vessel, and a transparent clot floated above. This was not the case in the portions abstracted subsequently.

The serum was of a bright golden color, and, when kept for twelve hours, partially coagulated, resembling jelly.

Specific gravity of the blood	1026.5
" " serum	1013.7
Solid constituents in 1000 parts of blood	124.59
" " " serum	43.03
" in serum of 1000 parts of blood	39.36
Water in 1000 parts of blood	875.41
" " serum	956.97

1000 parts of blood contained—

Water	875.41
Blood-corpuscles (dried organic constituents)	80.67
Albumen, fatty and extractive matter	37.66
Fibrin	1.04
Fixed saline constituents	5.22

1000 parts of blood contained—

Moist blood-corpuscles	336.76	Water	252.57
		Solid constituents	84.19
Liquor sanguinis	663.24	Water	622.84
		Solid constituents	40.40

15. *Testudo Polyphemus*, Daudin (male). Gopher. June 23.

This Gopher had been kept for five days, during which time it was abundantly supplied with vegetable food.

When the neck was cut, the blood flowed in a jet with considerable force, as from a severed artery of a warm-blooded animal.

This animal is remarkable for its muscular powers. It required all the force that I could exert with my arms to draw its head out of the shell. The adult will frequently support, and move about with a full-grown man upon their backs.

They live in troops in pine-barren countries, and subsist entirely upon vegetable substances. Their intestinal canal is modified so as to contain large stores of nutritive matters. The appearance of their viscera is represented in Fig. 9. By comparing this with the viscera of a carnivorous Chelonian, as the Snapping Turtle (*Chelonura serpentina*), Fig. 8, we see the modifications by which the alimentary canal is adapted to the habits and food of animals.

The shell of the Gopher is much softer, and its bony structure much thinner and imperfect, even to old age, than that of other Terrapins, as the *Emys serrata*. The shell of young Gophers is composed almost entirely of a material resembling horn, and contains little or no osseous matter. This is due to the character of their food, which contains the fixed alkaline and earthy salts in much less amount than animal food.

The serum was of a light yellow color, differing from the bright golden color of the serum of the *Emys serrata*, *Emys reticulata*, and *Emys Terrapin*. When treated with a drop of sulphuric acid and gently heated, the peculiar smell of the animal, similar to that of a Sheep, was developed.

Amount of blood obtained	2500 grains
Specific gravity of its blood	1030
" " serum	1018
Solid constituents in 1000 parts of blood	156.62
" " " serum	66.41
" in serum of 1000 parts of blood	60.00
Water in 1000 parts of blood	843.38
" " serum	933.59

1000 parts of blood contained—

Water	843.38
Blood-corpuscles (dried organic constituents)	87.28
Albumen, fatty and extractive matter	57.78
Fibrin	5.73
Fixed saline constituents	5.83

1000 parts of blood contained—

Moist blood-corpuscles	393.56	Water	302.67
		Solid constituents	90.89
Liquor sanguinis	606.44	Water	540.71
		Solid constituents	65.73

Blood of Birds.

16. *Ardea Nycticorax,* Linnæus (female). Night Heron. June 12.

This bird had its wing broken, and was also wounded in the neck, where some blood had been extravasated into the cellular tissue. The blood was drawn about two hours after its capture.

Specific gravity of the blood	1028
Solid constituents in 1000 parts of blood	127.11
" " " serum	50.00
" in serum of 1000 parts of blood	45.95
Water in 1000 parts of blood	872.89
" " serum	950.00

1000 parts of blood contained—

Water	872.89
Blood-corpuscles (dried organic constituents)	74.91
Albumen, fatty and extractive matter	43.41
Fibrin	2.20
Fixed saline constituents	6.59

1000 parts of blood contained—

Moist blood-corpuscles	315.84	Water	236.88
		Solid constituents	78.96
Liquor sanguinis	684.16	Water	636.01
		Solid constituents	48.15

17. *Syrnium nebulosum,* Linnæus. Barred Owl. May 14.

This bird had been shot in the eye, wing, and other parts of the body, and kept without food for twenty-four hours.

Solid constituents in 1000 parts of blood	160.34
" " " serum	54.94
" in serum of 1000 parts of blood	48.81
Water in 1000 parts of blood	839.66
" " serum	945.06

1000 parts of blood contained—

Water	839.66
Blood-corpuscles (dried organic constituents)	101.08
Albumen, fatty and extractive matter	46.51
Fibrin	4.69
Fixed saline constituents	8.06

1000 parts of blood contained—

Moist blood-corpuscles	427.36	Water	320.52
		Solid constituents	106.84
Liquor sanguinis	572.64	Water	519.14
		Solid constituents	53.50

18. *Cathartes atratus,* Wils. Black Turkey-Buzzard. Sept. 8.

The blood had a strong, disagreeable, musky odor, similar in all respects to that

of the bird itself. When the serum was treated with sulphuric acid and gently heated, this smell was developed with great power.

The odor of the Turkey-buzzard is not only disagreeable in the extreme, but also lasts for a great length of time. It was difficult to remove it from the hands, and my laboratory was fumigated for a considerable length of time after this analysis.

The serum, like that of several Terrapins, was of a bright orange color.

The fibrin was unusually soft and inconsistent, and much of it dissolved during the process of washing.

Solid constituents in 1000 parts of blood	200.83
" " " " serum	51.85
" " in serum of 1000 parts of blood . . .	43.70
Water in 1000 parts of blood	799.17
" " serum	948.15

1000 parts of blood contained—

Water	799.17
Blood-corpuscles (dried organic constituents)	150.47
Albumen, fatty and extractive matters	41.62
Fibrin	.41
Fixed saline constituents	8.33

1000 parts of blood contained—

Moist blood-corpuscles	626.88	Water	470.16
		Solid constituents . . .	156.72
Liquor sanguinis	373.12	Water	329.01
		Solid constituents . . .	44.11

The number of the analyses of the blood of Birds which have been published is very limited. The following analyses of the blood of the Goose and Hen were made by Nasse:—

	Water.	Blood-corpuscles.	Albumen and extractive matter.	Fibrin.	Fat.	Soluble salts.	Insoluble salts.
Goose . . .	814.88	121.45	50.78	3.46	2.56	6.87	1.09
Hen . . .	793.24	144.75	48.25	4.67	2.03	6.97	1.82

The following analyses of the blood of domestic Birds were made by Dumas and Prevost:—

	Water.	Solid constituents.	Blood-corpuscles.	Residue of serum.
Raven	797.0	203.0	146.6	56.4
Heron	808.2	191.8	132.6	59.2
Duck	765.2	234.8	150.1	84.7
Hen	779.9	220.1	157.1	63.0
Pigeon	797.4	202.6	155.7	46.9

Blood of Mammals.

19. *Common Cur-Dog.* June 28.

Previously to this analysis, the dog had been poorly fed, principally upon vegetable food.

The blood coagulated rapidly; the clot was large, and the relative amount of serum small. After standing for several hours, 400 grains of blood yielded not more than 40 grains of serum suitable for analysis.

The serum was transparent, but of a bright red color.

Specific gravity of the blood	1043.6
Solid constituents in 1000 parts of blood	188.13
" " " serum	128.95
" in serum of 1000 parts of blood	120.18
Water in 1000 parts of blood	811.87
" " serum	871.05

1000 parts of blood contained—

Water	811.87
Blood-corpuscles (dried organic constituents)	62.72
Albumen, fatty and extractive matter	116.33
Fibrin	3.04
Fixed saline constituents	6.04

1000 parts of blood contained—

Moist blood-corpuscles	263.64	Water	197.73
		Solid constituents	65.91
Liquor sanguinis	736.36	Water	613.14
		Solid constituents	123.22

20. *Common Cur-Dog*, used in the preceding analysis. August 7th.

For a week previous to this analysis, the dog was supplied with more mutton than he could devour. Upon this diet of animal food, he became very fat and fleshy in a few days.

The blood coagulated in a few moments after it left the body.

Specific gravity of the blood	1045.5
" " serum	1030.5
Solid constituents in 1000 parts of blood	193.48
" " " serum	119.67
" in serum of 1000 parts of blood	109.64
Water in 1000 parts of blood	806.52
" " serum	880.33

1000 parts of blood contained—

Water	806.52
Blood-corpuscles (dried organic constituents)	78.04
Albumen, fatty and extractive matter	106.18
Fibrin	3.15
Fixed saline constituents	6.11

1000 parts of blood contained—

Moist blood-corpuscles	322.76	Water	242.07
		Solid constituents . . .	80.69
Liquor sanguinis	677.24	Water	564.45
		Solid constituents . . .	112.79

Andral, Gavarret, and Delafond, made no less than 222 analyses of the blood of 155 Mammals. The following results of their investigations may be compared with my analyses of the blood of cold-blooded animals.

		Water.	Blood-corpuscles.	Residue of serum.	Fibrin.
Blood of 17 Horses . . .	Mean	810.5	102.9	82.6	4.0
	Maximum	833.3	112.1	91.0	5.0
	Minimum	795.7	81.5	74.6	3.0
Blood of 14 Cattle . . .	Mean	810.3	99.7	86.3	3.7
	Maximum	824.9	117.1	93.6	4.4
	Minimum	799.0	85.1	82.9	3.0
Blood of 19 Sheep (Rambouillet breed)	Mean	815.3	98.1	83.5	3.1
	Maximum	830.3	109.6	96.6	3.8
	Minimum	808.7	82.5	74.7	2.6
Blood of 11 Sheep (cross variety)	Mean	810.8	106.1	80.3	2.8
	Maximum	827.2	123.4	87.7	3.4
	Minimum	789.8	94.6	74.7	2.3
Blood of 13 English Sheep . .	Mean	810.8	95.0	92.4	2.6
	Maximum	822.1	110.4	97.0	3.3
	Minimum	795.3	83.8	82.6	2.0
Blood of 6 English Swine . .	Mean	809.6	105.7	80.1	4.6
	Maximum	816.9	120.6	88.7	5.0
	Minimum	793.9	92.1	73.6	4.1
Blood of 2 Goats	Mean	804.0	101.4	91.4	3.2
	Maximum	809.2	105.7	92.0	3.5
	Minimum	798.8	97.2	90.8	2.6
Blood of 16 Dogs . . .	Mean	774.1	148.3	75.5	2.1
	Maximum	795.5	176.6	88.7	3.5
	Minimum	744.6	127.3	60.9	1.6

The following are the analyses of the blood of different Mammals made by Nasse. The extractive matter and insoluble salts of the blood are included with the albumen.

	Water.	Blood-corpuscles.	Albumen.	Fat.	Fibrin.	Soluble salts.
Horse . . .	804.75	117.13	67.85	1.31	2.41	6.82
Ox	799.59	121.86	66.90	2.04	3.62	5.98
Calf	826.71	102.50	56.41	1.61	5.76	7.00
Goat . . .	839.44	86.00	62.70	0.91	3.90	7.04
Sheep . . .	827.76	92.42	68.77	1.16	2.97	6.91
Rabbit . . .	817.30			1.90	3.80	6.28
Swine . . .	768.94	145.35	72.78	1.95	3.95	6.74
Cat	810.02	113.39	64.46	2.70	2.42	7.01
Dog	790.50	123.85	65.19	2.25	1.93	6.28

Dumas and Prevost analyzed the blood of numerous animals. The method of analysis which they employed was similar, in some respects, to that of Andral,

Gavarret, and Delafond. The fibrin, however, was not determined. The following are the results which they obtained with the blood of the Mammals:—

	Water.	Solid constituents.	Blood-corpuscles.	Solid matter of serum.
Ape (*Simia callitriche*)	776.0	224.0	146.1	77.9
Dog	810.7	189.3	123.8	65.5
Cat	795.3	204.7	120.4	84.3
Horse	818.3	181.7	92.0	89.7
Calf	826.0	174.0	91.2	82.8
Sheep	829.3	170.7	93.5	77.2
Goat	814.6	185.4	102.0	83.4
Rabbit	837.9	162.1	93.8	68.3
Guinea-pig	784.8	215.2	128.0	87.2

Having examined in detail the blood of cold and warm-blooded animals in a normal condition, we shall next compare the individual results and analyses together, and endeavor to point out the characteristic distinctions of the blood of these two great classes of animals.

Amount of Blood existing in the Bodies of Warm and Cold-blooded Animals in a Normal State.

In determining the amount of blood, several methods have been employed by different chemists and physiologists.

M. Valentin[1] adopted the following ingenious mode:—

Having weighed the animal, he abstracted a definite amount of blood, determined its solid constituents, and then injected a given quantity of distilled water into the bloodvessels. Time was allowed for the diffusion of this by the circulatory apparatus throughout the mass of the blood. A fresh portion of blood was then abstracted, and the amount of solid matters determined. The relation between the amount of solid matters in the blood first drawn and the blood diluted with a given quantity of distilled water, enabled him to calculate the quantity of the entire blood of the animal.

Although this method is sufficiently accurate for general purposes, still the following objections have been urged against it with justice.

The water injected is not diffused uniformly throughout the mass of blood. This is determined by the fact that the blood drawn from different veins yields different proportions of water and solid matters. When an excess of water is injected into the circulatory system, it has a tendency to lodge in certain organs, as the kidneys and spleen, and in a less degree in the lungs. Other circumstances affect the accuracy of the results; as the loss of blood in any of the steps of the operation, the elimination of the water by evaporation from the surface of the lungs and skin, and by the action of the kidneys, and exosmose into the surrounding tissues in the interval of time between the injection of the water and the abstraction of the second portion of blood.

[1] Rept. der Physiol., Bd. s. 281-293.

If, however, the experiment be carefully performed, without allowing any loss of blood, or too great a length of time to elapse between the injection of the water and the abstraction of the second portion of blood, results approaching very nearly to the truth may be obtained.

Another method has been suggested, dependent for its accuracy upon the fact that iron exists only in the blood-corpuscles and hair, and consequently when the latter is shaved off, it will be found only in the former.

A definite portion of blood is abstracted, and the proportion of iron determined. The whole animal is then burned, the ashes collected, and the amount of iron ascertained. By a comparison of this with the amount existing in a definite quantity of blood, the whole amount of blood may be determined. This method, if practicable, promises accurate results.

Another method, proposed by Lehmann,[1] is founded upon the fact that only a definite amount of grape sugar can exist in the blood at any one time, without its elimination by the kidneys.

Having ascertained how much grape sugar the blood may normally contain under favorable circumstances, the quantity of blood contained in an animal may be calculated by ascertaining the quantity of sugar which must be introduced into the circulatory fluid in order to make it pass into the urine.

The methods of Valentin and Lehmann might be applicable to warm-blooded animals, whose circulation is rapid, and whose excretions and secretions are correspondingly abundant. They are, however, wholly inapplicable to cold-blooded animals.

In the first place, the circulation in this class is sluggish, and the blood, owing to the peculiarities of the structure of the circulatory apparatus, is not diffused uniformly to all the organs and tissues, as in the higher animals. In the second place, the secretions and excretions are exceedingly slow, and small in amount. Many animals of this class do not void their urine more than once in a month during starvation, and then in exceedingly small quantities. In many the bladder is absent, and where it does exist, even supposing that the urine was rapidly excreted, owing to the structure and position of the urinary apparatus, it is next to impossible to draw off the contents of the bladder.

From these considerations, then, it would be utterly impossible to determine the amount of blood in cold-blooded animals, by injecting into the circulatory system either water or grape sugar.

The method, also, of determining the quantity of blood from the relative proportion of iron in a definite amount of blood and in the ash of the whole body, would also, in many animals of this class, be absolutely impossible. The Chelonians,

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[1] Lehmann's Physiological Chemistry, translated by G. E. Day, Amer. edit., Philad., 1855, I, 639.
Other methods of determining the amount of blood have been proposed, but not practised, by the following physiologists: Vogel, Pathol. Anat. des menchl. Körpers, Leipz., 1845, s. 59 (or English translation, p. 84). Dumas, Chim. Physiol. et Med., Paris, 1848, p. 326. Weisz, Zeitsch. d. k. k. Gesellsch. d. Aertze, Dec. 1847, s. 203–229.

are provided with such an enormous external skeleton, that the errors in the calculation of the amount of iron in this would be numerous.

The only practical method which I was able to devise, was, to cut the jugular veins and arteries, and, stretching the neck out, hold the body perpendicular, with the head downwards. The contraction of the heart, bloodvessels, and capillaries, aided by gravity, expelled very nearly all the blood; a fact which was often proved by the thin, watery aspect of the last portions.

This method is more accurate in cold than warm-blooded animals, because their nervous and muscular system, requiring but little nutriment from the blood, the heart continues to beat, and the muscles, bloodvessels, and capillaries to contract, for hours after almost all the blood has been abstracted. In warm-blooded animals, the heart ceases to beat, and the contractility of the muscular system is lost, when not more than one-third of the blood has been abstracted. This method, then, which I employed to determine the amount of blood in cold-blooded animals, should not be condemned because it is not applicable to warm-blooded animals.

Great discrepancies have prevailed amongst physiologists with regard to the amount of blood contained in the bodies of warm-blooded animals.

Blumenbach estimated the quantity in an adult man at 8.5 to 11 pounds, and Reil at 44 pounds.

M. Valentin, by his method of injecting water, arrived at the following results. The numbers represent the relation existing between the quantity of blood and the weight of the body.

Large Dogs (the mean of four experiments)	as 1 : 4.5
A lean, debilitated Sheep	as 1 : 5.02
Cats, female (the mean of two experiments)	as 1 : 5.78
A large female Rabbit	as 1 : 6.20

From these data, he estimated the amount of human blood to be

Male sex	as 1 : 4.36
Female sex	as 1 : 4.93

At the present day, the blood is generally estimated at 22 pounds, which is equal to about the eighth part of the weight of the body.

Lehmann[1] determined the amount of blood in the bodies of two criminals, who were decapitated, to be from 17.5 to nearly 19 pounds, or one-eighth the weight of their bodies.

From numerous careful examinations of cold-blooded animals, by the method previously described, I have arrived at the following results, which must be considered only as an approximation to the truth.

Amount of blood in Serpents	$\frac{1}{16}$ to $\frac{1}{13}$	of the weight of body.
" *Emys terrapin*	$\frac{1}{11}$ to $\frac{1}{14}$	" "
" *Emys serrata*	$\frac{1}{13}$ to $\frac{1}{16}$	" "
" *Testudo polyphemus*	$\frac{1}{14}$ to $\frac{1}{17}$	" "

[1] Loc. cit., p. 638.

Our investigations have shown that *the blood is far less abundant in cold than in warm-blooded animals.*

This fact is important, because it will aid us in the investigation of many of the phenomena of cold-blooded animals, and in the explanation of the differences which distinguish the two great classes of animals.

Color of the Blood and Serum.

The arterial blood of cold-blooded animals is never of that bright red color of the arterial blood of warm-blooded animals, on account of the mixture of the arterial and venous blood in the common ventricle of the heart. For the same reason, the venous blood is not of so dark a color as that of warm-blooded animals.

The color of the serum in most Reptiles—as Ophidians, Batrachians, Fishes—and some Chelonians—as the Gopher (*Testudo polyphemus*)—is of a light yellow color.

In many carnivorous Terrapins—as the Yellow-belly Terrapin (*Emys serrata*), Chicken Terrapin (*Emys reticulata*), and Salt-water Terrapin (*Emys terrapin*)—the serum is of a golden color.

In most Birds and Mammalia which I have examined, the serum is of a light yellow color. In the Black Turkey-buzzard (*Cathartes atratus*), it is of a golden color.

Odor of Animals.

The strong smell of both cold and warm-blooded animals appears to reside especially in the serum, and may be developed by treating the serum with a little sulphuric acid, and applying a gentle heat. I have demonstrated this fact in numerous instances, and often in the serum of disagreeable animals, with disgusting power. The odor of animals is also due, as in the Alligator and Rattlesnake, to peculiar glands. The secretion of the anal gland of the Rattlesnake emits such a powerful and disagreeable odor, that it may produce giddiness of the head and sickness of the stomach.[1]

Specific Gravity of the Serum and Blood.

These results were accurately determined upon the balance used in all my analyses, which, as we have before stated, was capable of indicating $\frac{1}{1000}$th of a grain.

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[1] In dissecting a large male Rattlesnake (*Crotalus durissus*), I accidentally cut the anal gland, and the odor was so peculiar, heavy, and disgusting, and exerted such an effect upon the head, that it was with the greatest difficulty that the dissection and drawing were completed.

Table of the Specific Gravities of the Blood and Serum of Animals.

Name of observer.	Name of animal.	Sp. gr. of blood.	Sp. gr. of serum.
Jos. Jones	*Psammophis flagelliformis* (Coachwhip Snake)	1036.0	
"	*Alligator Mississippiensis* (Alligator)	1046.0	
"	*Chelonia caretta* (Loggerhead Turtle)	1032.5	1014.8
"	*Chelonura serpentina* (Snapping Turtle)	1025.5	1013.6
"	*Emys terrapin* (Salt-water Terrapin)	1035.3	1012.7
"	*Emys reticulata* (Chicken Tortoise)	1034.0	
"	*Emys serrata* (Yellow-bellied Terrapin)	1026.5	1013.7
"	*Emys serrata* (Yellow-bellied Terrapin)	1029.6	1014.0
"	*Testudo polyphemus* (Gopher)	1030.0	1018.0
"	*Testudo polyphemus* (Gopher)	1037.0	1017.0
"	Common Cur-Dog	1043.0	
"	Common Cur-Dog	1045.5	1030.5
Becquerel and Rodier	Pregnant Women, Mean	1051.5	1025.5
	Pregnant Women, Maximum	1055.1	1026.8
	Pregnant Women, Minimum	1046.2	1023.6
"	20 human beings, mean	1055.0	1026.1
"	10 human beings, mean	1056.0	
"	11 Men, mean	1060.2	1028.0
"	8 Females, mean	1057.5	1027.4
Lehmann	Human	1057.4	1028.0

From this table we learn that *the blood becomes more concentrated as the organs, and apparatus, and intelligence of animals are developed.*

Table showing the Amounts, in 1000 parts, of the Water and Solid Matters of the Blood and Serum of different Animals.

COLD-BLOODED ANIMALS.

BLOOD OF INVERTEBRATE ANIMALS.

Name of observer.	Name of animal.	Water in 1000 parts of blood.	Solid matter in 1000 parts of blood.	Water in 1000 parts of serum.	Solid matter in 1000 parts of serum.	Solid matter in serum of 1000 parts of blood.
C. Schmidt	*Anodonta cygnea* (Pond Mussel)	999.146	0.854			0.565
Harless & Bibra	*Helix pomatia* (Shell Snail)	985.482	14.518			8.398
" "	*Loligo and Eledone* (Cephalopods)	992.67	7.33			4.70
	BLOOD OF VERTEBRATE ANIMALS.					
	Fishes.					
Jos. Jones	*Trygon sabina* (Stingray)	884.20	115.80			
"	*Zygæna malleus* (Hammerhead Shark)	861.14	138.86	929.31	70.96	65.50
"	*Lepisosteus osseus* (Garfish)	886.70	113.30	945.55	59.45	56.05
J. F. Simon	Carp	872.00	128.00			83.85
"	Tench	900.00	100.00			68.80
Dumas & Prevost	Trout	863.70	136.30			72.50
" "	Eelpout	886.20	113.80			65.70
" "	Eel	846.00	154.00			94.00
	Aquatic Reptiles					
Jos. Jones	*Rana catesbœana* (Bullfrog)	832.51	167.49	938.07	61.93	54.96
Dumas & Prevost	Frog	884.60	115.40			46.40
Jos. Jones	*Chelonia caretta* (Loggerhead Turtle)	879.19	120.81	950.56	49.44	45.82
"	*Chelonura serpentina* (Snapping Turtle)	895.00	105.00	951.32	48.68	45.80
"	*Emys terrapin* (Salt-water Terrapin)	845.28	154.72	956.17	43.83	38.75
"	*Emys reticulata* (Chicken Tortoise)	846.98	153.02	936.42	63.58	57.51
"	*Emys serrata* (Yellow-bellied Terrapin)	875.41	124.59	956.97	43.03	39.36
"	*Alligator Mississippiensis* (Alligator)	823.86	176.14	909.20	90.80	82.05
	Land Reptiles.					
J. F. Simon	*Bufo variabilis*	848.20	151.80			112.33
Jos. Jones	*Heterodon platyrhinos* (Hog-nose Viper)	833.24	166.76	937.50	62.50	55.55
"	*Heterodon niger* (Black Viper)	860.57	139.43	925.11	74.89	69.67
"	*Psammophis flagelliformis* (Coachwhip Snake)	818.30	181.70	934.22	65.78	57.62
"	*Coluber constrictor* (Black Snake)	788.63	211.37	898.58	101.42	89.01
"	*Testudo polyphemus* (Gopher)	843.38	156.62	933.59	66.41	60.00

WARM-BLOODED ANIMALS.

BLOOD OF BIRDS.

Name of observer.	Name of animal.	Water in 1000 parts of blood.	Solid matters in 1000 parts of blood.	Water in 1000 parts of serum.	Solid matters in 1000 parts of serum.	Solid matters in serum of 1000 parts of blood.
Nasse	Goose	814.88	185.12			55.78
"	Hen	793.24	206.76			53.25
Dumas & Prevost	Hen	779.90	220.10			63.00
" "	Pigeon	797.40	202.60			46.90
" "	Duck	765.20	234.80			84.70
" "	Raven	797.00	203.00			56.40
" "	Heron	808.20	191.80			59 20
Jos. Jones	*Ardea nycticorax* (Heron)	872.89	127.11	950.00	50.00	45.95
"	*Syrnium nebulosum* (Hooting Owl)	839.66	160.34	945.06	54.94	48.81
"	*Cathartes atratus* (Black Turkey-buzzard)	799.17	200.83	948.15	51.85	43.70

BLOOD OF MAMMALS.

Name of observer.	Name of animal.	Water in 1000 parts of blood.	Solid matters in 1000 parts of blood.	Water in 1000 parts of serum.	Solid matters in 1000 parts of serum.	Solid matters in serum of 1000 parts of blood.
Andral, Gavarret, and Delafond	17 Horses { Mean	810.50	189.50			82.60
	17 Horses { Maximum	833.30	204.30			91.00
	17 Horses { Minimum	795.70	166.70			74.60
Nasse	Horse	804.75	195.25			70.85
Dumas & Prevost	Horse	818.30	181.70			89.70
Andral, Gavarret, and Delafond	14 Cattle { Mean	810.30	189.70			86.30
	14 Cattle { Maximum	824.90	201.00			93.60
	14 Cattle { Minimum	799.00	175.10			82.90
Nasse	Ox	799.59	200.41			69.90
Dumas & Prevost	Calf	826.00	174.00			82.80
Andral, Gavarret, and Delafond	30 Sheep, mean	813.50	186.50			82.40
Nasse	Swine	768.94	231.06			75.78
"	Rabbit	817.30	182.70			68.30
Dumas & Prevost	Rabbit	837.90	162.10			
" "	Goat	814.60	185.40			83.40
Nasse	Goat	839.44	160.56			65.70
Andral, Gavarret, and Delafond	16 Dogs, mean	774.10	225.90			75.50
Nasse	Dog	790.50	209.50			68.19
Dumas & Prevost	Dog	810.70	189.30			65.50
Jos. Jones	Common Cur-Dog	811.87	188.13	871.05	128.95	120.18
"	Common Cur-Dog	806.52	193.48	880.33	119.67	109.64
Dumas & Prevost	Cat	795.30	204.70			84.30
Nasse	Cat	810.02	189.98			68.46
M. Lecanu	Man { Maximum	853.135	221.37			78.27
	Man { Minimum	778.625	146.86			57.89
	Man { Mean	815.880	184.12			68.08

A careful comparison of these results leads to the following conclusions:—

1. The proportion of water is greatest in the Invertebrata. The blood of these animals has, according to Genth, a specific gravity not many degrees above that of common water.

2. Amongst vertebrate animals, the amount of water existing in the blood is greatest in Fishes and Aquatic Reptiles, and least in Serpents, Birds, and Mammals. As a necessary consequence, the solid matters of the blood are least in the Invertebrata, Fish, and Aquatic Reptiles, and greatest in Serpents, Birds, and Mammalia.

3. *It may be laid down as a general law, that as the organs and apparatus of the animal are developed, and the temperature and intellect correspondingly increased, the blood becomes richer in organic constituents.*

The blood of serpents appears, at first sight, to form an exception. The large amount of solid constituents, however, existing in their blood, is readily accounted for, when we consider their habits. These Reptiles seldom or never drink water; consequently, the fluids of their bodies are derived from the animals which they consume. In all animals, the water of the blood and tissues is continually evaporating from the surface of the lungs and body. The amount of evaporation is in proportion to the structure, habits, and temperature of the animal, and the temperature and moisture of the atmosphere. It is greatest in warm-blooded animals, and in hot and dry climates. Amongst cold-blooded animals, it is greatest in those having naked skins, and least in those covered by scales, bone, and horn. No matter how slow and small this evaporation, if it be not counteracted by a corresponding supply of water, the blood necessarily becomes concentrated, and yields a larger proportion of solid constituents upon analysis.

4. Our knowledge is as yet too limited to develop any laws respecting the amount of water and solid materials which characterize the blood of each species and genus. By comparing the analysis of the blood of the Mammalia, we see that the proportions of its constituents vary as much in individuals of the same species as in individuals of remotely separated genera.

Table of the Moist Blood-corpuscles and Liquor Sanguinis in 1000 parts of Blood.

Observer.	Name of animal.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
		Blood-corpuscles.	Water.	Solid matters.	Liquor sanguinis.	Water.	Solid matters.
Jos. Jones	*Zygæna malleus* (Shark)	293.44	220.08	73.36	706.56	641.06	65.50
"	*Lepisosteus osseus* (Garfish)	229.00	171.75	57.25	771.00	714.95	56.05
Dumas & Prevost	Trout	275.20	206.40	68.80			
" "	Eelpout	192.40	144.30	48.10			
" "	Eel	240.00	180.00	60.00			
Jos. Jones	*Rana pipiens* (Bullfrog)	450.12	337.59	112.53	549.88	494.92	54.96
Dumas & Prevost	Frog	276.00	207.00	69.00			
Jos. Jones	*Heterodon platyrhinos* (Hog-nose Viper)	444.84	333.63	111.21	555.16	499.61	55.55
"	*Heterodon niger* (Black Viper)	270.40	202.80	67.60	729.60	657.77	71.83
"	*Psammophis flagelliformis* (Coach-whip Snake)	488.80	366.60	122.20	511.20	451.70	59.50
"	*Coluber constrictor* (Black Snake)	469.20	351.90	117.30	530.80	436.73	94.07
"	*Chelonia caretta* (Turtle)	289.52	217.14	72.38	710.48	662.05	48.43
"	*Chelonura serpentina* (Alligator Cooter)	235.40	176.55	58.85	764.60	718.45	46.15
"	*Emys terrapin* (Salt-water Terrapin)	447.28	335.46	111.82	552.72	509.82	42.90
"	*Emys reticulata* (Chicken Terrapin)	372.00	279.00	93.00	628.00	567.98	60.02
"	*Emys serrata* (Yellow-belly Terrapin)	336.76	252.57	84.19	663.24	622.84	40.40
"	*Testudo polyphemus* (Gopher)	393.56	302.67	90.89	606.44	540.71	65.73
"	*Alligator Mississippiensis* (Alligator)	364.08	273.06	91.02	635.92	550.80	85.12
Nasse	Goose	485.80	364.35	121.45			
"	Hen	579.00	434.25	144.75			
Dumas & Prevost	Hen	628.40	461.30	157.10			
" "	Duck	600.40	450.30	150.10			
" "	Pigeon	622.80	467.10	155.70			
" "	Raven	586.40	339.80	146.60			
" "	Heron	530.40	367.80	132.60			
Jos. Jones	*Ardea nycticorax* (Heron)	315.84	236.88	78.96	684.16	636.01	48.15
"	*Syrnium nebulosum* (Hooting Owl)	427.36	320.52	106.84	572.64	519.14	53.50
"	*Cathartes atratus* (Black Buzzard)	626.88	470.16	156.72	373.12	329.01	44.11
Andral, Gavarret, and Delafond	17 Horses { Mean	411.60	308.70	102.90			
	Maximum	448.40	336.30	112.10			
	Minimum	326.00	244.50	81.50			
Nasse	Horse	468.52	351.39	117.13			
Andral, Gavarret, and Delafond	30 Sheep, mean	404.40	303.30	101.10			
Nasse	Sheep	369.68	277.26	92.42			
Andral, Gavarret, and Delafond	14 Cattle { Mean	398.80	299.10	99.70			
	Maximum	468.40	351.30	117.10			
	Minimum	340.40	255.30	85.10			
" "	6 Swine, English breed, mean	422.80	317.10	105.70			
" "	16 Dogs { Mean	593.20	444.90	148.30			
	Maximum	706.40	529.80	176.60			
	Minimum	509.20	387.90	121.30			
Jos. Jones	Common Cur-Dog	363.64	197.73	65.91	736.36	613.14	125.22
"	Common Cur-Dog	322.76	242.07	80.69	677.24	564.45	112.79

The following general facts and conclusions have been derived from a careful comparison of the results contained in this table, and those derived from our previous investigations.

In the Invertebrata, the number of blood-corpuscles is very small in comparison

with the number which exists in the blood of the Vertebrata. In this class, we find only colorless corpuscles.

In the *Branchiostoma* or *Amphioxus*, the connecting link between the highest orders, the Mollusca and Fishes, the blood, like that of the Invertebrata, is described as containing only colorless corpuscles, and exceedingly rich in water, and correspondingly poor in solid constituents.

As the organs and apparatus are developed, the blood is correspondingly improved.

The increased development of the cerebro-spinal system, and the organs of vertebrate animals, is attended by a corresponding increase in the solitary gland-cells of the blood.

In this class, the number of blood-corpuscles is, as a general rule, least in cold-blooded animals, and greatest in Birds and Mammals. There are, however, exceptions to this rule. I have found the number of blood-corpuscles in some cold-blooded animals, especially Serpents, higher than that of some Birds and Mammals.

The following table will illustrate this fact:—

Name of observer.	Name of animal.	Blood-corpuscles in 1000 parts of blood.
Jos. Jones	*Rana catesbæana* (Bullfrog)	450.12
"	*Emys terrapin* (Salt-water Terrapin)	447.28
"	*Alligator Mississippiensis* (Alligator)	364.08
"	*Heterodon platyrhinos* (Hog-nose Viper)	444.84
"	*Psammophis flagelliformis* (Coachwhip Snake)	488.80
"	*Coluber constrictor* (Black Snake)	469.20
"	*Ardea nycticorax* (Heron)	315.84
"	*Syrnium nebulosum* (Hooting Owl)	427.36
Andral, Gavarret, and Delafond	Horse	326.20
Dumas and Prevost	Horse	368.00
" "	Goat	408.00
Nasse	Goat	344.00
Jos. Jones	Cur-Dog	363.64
"	Cur-Dog	322.76
Dumas and Prevost	Dog	495.20
" "	Calf	364.80

Notwithstanding the differences in the number of blood-corpuscles, the differences of temperature were preserved, not only between the warm and cold-blooded animals, but also between the individual species of each class.

The thermometer indicated a temperature of over 100° in the Heron, having only 364.08 parts of blood-corpuscles, whilst in the Frog, Serpents, and Chelonians, having nearly double the number of blood-corpuscles in a given quantity of blood, the thermometer indicated a temperature several degrees below that of the surrounding medium.

Several physiologists assert that the sole office of the blood-corpuscles is to carry oxygen in, and convey carbonic acid gas out of the animal economy. If this be true, the temperature of an animal would, at first sight, seem to be determined, in great measure, by the number of its blood-corpuscles; but the temperature also depends upon the velocity of transfer of the oxygen, and consequently upon the rapidity of the circulation. Many facts, however, might be brought forward, to

prove that the office of the blood-corpuscles is not solely the introduction of oxygen, and the carrying out of carbonic acid. The following facts will show that the liquor sanguinis is also active in the performance of these important offices.

In the capillaries and bloodvessels, the colored corpuscles rush along in the centre of the streams, whilst pure liquor sanguinis alone is in contact with the walls of the vessels. In the capillaries of the lungs, the oxygen, from this arrangement, must necessarily be absorbed first by the liquor sanguinis. Again, in no case do we find the organic cells, the active agents in all secretion and excretion, in immediate contact with the blood-corpuscles. They are separated from them by the coats of the capillaries, and a structureless basement membrane. The same is true of the anatomical elements of the muscular tissue. From whence do they derive oxygen, a continuous supply of which is absolutely necessary for the life and activity of every living molecule of organized beings? The same argument will also prove that the blood-corpuscles are not the sole agents in the conveyance of carbonic acid gas out of the organs and tissues.

These conclusions can be sustained by numerous examples.

Do we find blood-corpuscles in plants? Do we find blood-corpuscles in the lowest orders of invertebrate animals? These bodies absorb oxygen, and give out carbonic acid gas, notwithstanding the absence of blood-corpuscles. Spallanzani[1] has long since demonstrated that all organized bodies, whether living or dead, possess the property of absorbing oxygen and giving out carbonic acid gas.

We do not for one moment deny that one important office of the blood-corpuscles is the absorption of gases, for it has been often demonstrated that blood containing its corpuscles possesses far greater powers of absorbing oxygen, nitrogen, and carbonic acid than pure serum. We wish to show that this is not the sole office of the blood-corpuscle, because it is performed by the liquor sanguinis, and all organic matters, whether living or dead; and respiration is carried on in plants and the lowest animals, which are without blood-corpuscles; and an increase in the number of blood-corpuscles is not necessarily followed by an increase in the temperature.

What, then, are the principal offices of the blood-corpuscles, and what does an increase in their numbers denote?

These questions can only be answered by a consideration of their constitution, and their relations with the liquor sanguinis by which they are surrounded.

Each corpuscle is a cell, resembling, in its nutrition, growth, and general structure, the active agents in the formation, elaboration, and separation of all secretions and excretions. Their cell walls possess the property of separating from the surrounding medium certain peculiar organic and mineral compounds. If a blood-corpuscle be placed in water, it swells up, and finally bursts. If it is placed in a solution denser than its internal contents, they pass out more rapidly than the exterior solution passes in, and the cell wall shrivels up. The same physical laws of endosmose are at work in the animal economy. A mutual action and reaction is incessantly carried on between the interior contents of the blood-corpuscles and the exterior liquor sanguinis. Whenever water, or liquids of low specific gravity,

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[1] Memoirs on Respiration, by Lazarus Spallanzani. Edited by John Lenebier. London, 1805.

are introduced into the circulatory system, they dilute the serum, and immediately there is an endosmose of the less dense fluid into the denser contents of the corpuscles. Whenever water is withheld, the liquor sanguinis continually loses this element by evaporation from the surface of the lungs and skin, and by the action of the kidneys, becomes denser than the contents of the corpuscles, and exosmose takes place into the surrounding medium. The cell-wall modifies the physical and chemical properties of every molecule of liquor sanguinis that passes through its structure.

The researches of C. Schmidt have shown that the fluid contents of the blood-corpuscles contain, in addition to peculiar organic matters, a preponderance of the phosphates and potash salts; whilst the liquor sanguinis contains the chloride of sodium in large amount, with a little chloride of potassium and phosphate of soda.

In the blood-cells, the fatty acids and globulin are combined both with potash and soda; whilst in the plasma, the organic materials are combined only with soda. The researches of Liebig, confirmed by those of Schmidt, have shown that the fluid contained in the tubules of muscles is, like that of the blood-corpuscles, exceedingly rich in the phosphates and potash salts. The phosphates also exist in large amount in the brain.

These facts render it highly probable that the office of the blood-corpuscles, taken collectively, is that of an immense gland, which separates and elaborates from the liquor sanguinis those organic and inorganic compounds which constitute the most important part of the structure of the muscles and brain.

In the Mammalia, we have an increase not only by weight, but also an immense increase in numbers of the blood-corpuscles, owing to their greatly diminished size, and the amount of secreting surface exposed to the intercellular fluid is correspondingly increased. This being the case, the blood of these animals must be more highly elaborated, and all their organs and apparatus correspondingly developed.

In the present state of our knowledge, notwithstanding the numerous theories which have been ably advocated by different physiologists and anatomists, we are still ignorant of the exact mode of origin of the blood-corpuscles.

Structure of the Blood-corpuscles.

There is a great want of accordance in the descriptions of the structure of the colored blood-corpuscle, and its action under different chemical reagents. Some of the highest authorities are opposed to each other in their statements. I shall confine myself merely to the results of my own observations.

The size and form of the blood-corpuscle vary with the animal. In most of the Mammalia, they are biconcave circular discs.

In Birds, Reptiles, and Fishes, they are biconvex, ellipsoidal, or rounded discs. In the Shovel-nosed Shark (*Zygæna malleus*) and the Loggerhead Turtle (*Chelonia caretta*), they are very nearly of a circular form.

In all adult Mammals—as Dogs, Cats, Raccoons, Squirrels, Deer, Sheep, Moles, &c.—which I have examined, a nucleus is absent.

In Birds, Reptiles, and Fishes, a nucleus is always present. The convexity of the blood-corpuscle in these animals is due to the internal nucleus. When viewed

edgewise, as they roll over, this central prominence is rendered evident, standing out from the flattened disc.

The action of acetic acid shows that the exterior cell-wall is connected at the centre with the interior nucleus. The first action of acetic acid, which is almost instantaneous, is to reverse the shape of the blood-corpuscles. They become expanded around the periphery, whilst they remain of the same diameter at the centre, thus forming an hour-glass or dumb-bell figure when viewed in profile. The central portion maintains its diameter, which is that of the nucleus plus the thickness of the attached exterior cell-wall. Generally, the swelling is greatest at the extremities of the ellipsoidal disc. In some cases, the entire circumference of the disc swelled, leaving a central depression, corresponding to the internal nucleus. The next change effected by acetic acid, is to render the exterior cell-wall perfectly transparent, and in some cases to dissolve it completely, thus setting free the nuclei.

Acetic acid renders the nuclei more distinct, and in many instances renders visible a still smaller body, the original rudiment of the blood-corpuscle. The nucleoli are situated sometimes at the centre, and at others attached to the side of the nuclei.

The blood-corpuscles of these animals, then, correspond in structure to many other cells, having a cell-wall, nucleus, and nucleolus.

The best method of viewing the action of acetic acid, is to place a drop of blood upon a glass slide, and, having adjusted it to the focus of the microscope, touch its border with a drop of concentrated acetic acid, and observe, under the microscope, the line where the acetic acid and blood are mingling. Here we will see the blood-corpuscles changing from ellipsoidal, convex discs to hour-glass or dumb-bell figures and biconcave discs, and almost immediately becoming transparent, and exhibiting nothing but the central nucleus with its nucleolus. I have verified these statements by examinations of the blood of numerous Fishes, Batrachians, Ophidians, and Chelonians.

The following figures will represent in a clear light the action of acetic acid. In order properly to illustrate their structure, the blood-corpuscles are represented in a much rougher manner and stronger light than they appear under the microscope.

FIG. 1.

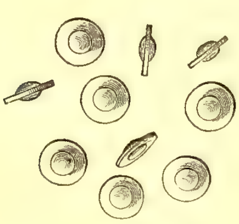


FIG. 2.

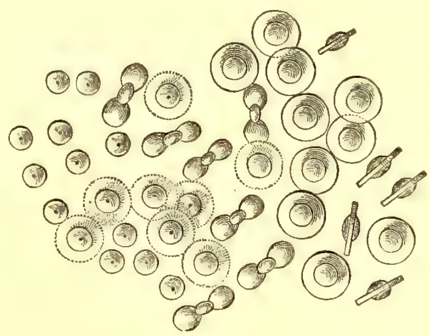


FIG. 1.—Blood-corpuscles of Hammer-head Shark (*Zygæna malleus*) in their normal condition. Mag. 210 diameters.

FIG. 2.—Blood-corpuscles of Hammer-head Shark (*Zygæna malleus*) treated with a drop of acetic acid, showing the different stages of its action. Mag. 210 diameters.

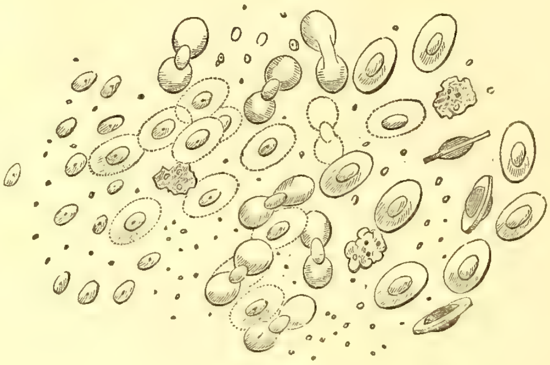


Fig. 3.—Blood-corpuscles of Salt-water Terrapin (*Emys terrapin*) in their normal condition. Mag. 210 diameters.

Fig. 4.—Blood-corpuscles of Salt-water Terrapin (*Emys terrapin*) acted upon by a drop of acetic acid, showing the nuclei, nucleoli, dumb-bell or hour-glass corpuscles, and beyond, where the acid has not extended, the normal corpuscles. Mag. 210 diameters.

Liquor potassa dissolves the cell-walls, nuclei, and nucleoli, alters the color of the blood to a brownish-yellow, and renders it viscid and ropy, like thick mucus. When treated with aqua ammonia, the corpuscles are at first altered in shape, sometimes elongated; and, in many cases, the cell-walls began to swell first toward the periphery, as in the action of acetic acid. In a short time, aqua ammonia, like liquor potassa, completely dissolves the corpuscles.

The colorless corpuscles are more numerous in cold than in warm-blooded animals. Amongst Chelonians, they are most numerous in the Salt-water Terrapins (*Emys terrapin*). In the blood of these Chelonians, numerous minute granules also abound. These minute granules increase during a rapid repair of the elements of the body. They were found to be much more numerous in the blood of Yellow-bellied Terrapins (*Emys serrata*) which had been deprived of food and drink for several weeks, and then transferred to a tub of water and liberally supplied with vegetable food for thirty to sixty days, than in the blood of those Terrapins which had been deprived of food and drink for several weeks.

Effects of Gases upon the Blood of Cold-blooded Animals.

Carbonic Acid Gas.

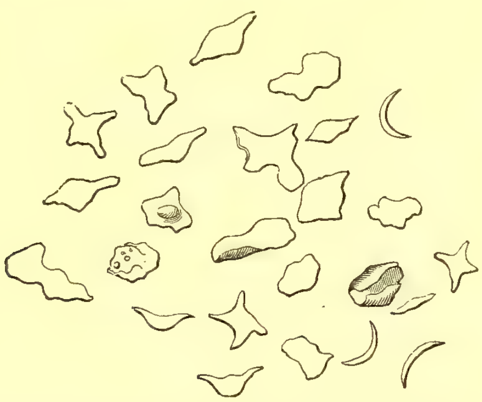
Salt-water Terrapins (*Emys terrapin*) and Yellow-bellied Terrapins (*Emys serrata*) were placed in large receivers containing this gas. They took long inspirations and expirations, resembling deep sighs. The noise made by the passage of the gas in and out of their lungs, resembled that often made by human beings dying from narcotic poisoning or congestion of the brain. The breathing of the Terrapins became more and more laborious, and less frequent, occurring at intervals of from ten to thirty minutes, and finally ceased in from ten to twelve hours.

The blood was of a much darker color than when the lungs were supplied with atmospheric air, and resembled much the venous blood of the Mammalia. Upon exposure to the air for a length of time, it became, upon its exterior, of a red

color. The heart and lungs, and the bloodvessels supplying the intestines, were engorged with black blood. The contractility of the muscles was completely destroyed.

The blood-corpuscles had undergone remarkable changes. They were shrivelled and contorted, presenting innumerable shapes, anything but ellipsoidal. These changes had taken place in the colored corpuscles in all the organs and tissues of the body. The effects of the gas appeared to have been confined principally to the exterior cell wall; for, when they were treated with acetic acid, the nuclei were brought out unchanged. The appearance of the colored corpuscles of a Yellow-bellied Terrapin (*Emys serrata*), which had been kept in the carbonic acid gas until its death, is represented in Fig. 5.

Fig. 5.



Blood-corpuscles of a Yellow-bellied Terrapin (*Emys serrata*) which had been kept without food or drink for several weeks, and then placed in a tub of water and abundantly supplied with vegetable food for 30 or 40 days, and finally placed in carbonic acid gas.

The urine of all these Terrapins which were confined in carbonic acid gas, contained grape sugar, which is not normally present in the excretions of the kidneys of these animals. The offices of the blood-corpuscles being arrested, oxygen being no longer conveyed into the system, grape sugar, the product of the action of the liver, was not decomposed, and, accumulating in the blood, was eliminated by the kidneys.

When Terrapins were employed which had been starved for a great length of time, the effect of carbonic acid gas upon the blood-corpuscles was not so evident, on account of the concentration of the blood, and the sluggishness of the metamorphoses of their tissues, and the rapidity with which they fell victims to the deleterious influences of this noxious gas. The effects of carbonic acid gas in altering the shape of the blood-corpuscles, were best seen in those Terrapins which had been deprived of food and drink for several weeks, and then transferred to a tub of water, and supplied with vegetable food.

These effects are not produced upon the blood-cells of warm-blooded animals, because they are so rapidly destroyed that the gas has not sufficient time to come in contact, in large quantities, with the corpuscles and materially alter their structure. Cold-blooded animals live much longer in carbonic acid gas than warm-

blooded animals, because their muscular and nervous systems are far more independent of the circulatory fluid, and the metamorphoses of the organic and inorganic elements of their fluids and solids are far less rapid.

Carbonic Oxide Gas.

A Corn Snake (*Coluber guttatus*) was placed in a jar of carbonic oxide gas. At first, its efforts to escape were unceasing and violent. Gradually, its respiration became more laborious; it gasped violently for breath; its motions became more spasmodic, and were succeeded by intervals of apparent exhaustion. It died in forty-five minutes after its introduction into the gas.

A Bullfrog (*Rana pipiens*) placed in the carbonic oxide gas presented similar phenomena, but died in a much shorter time, about ten minutes. This difference of time was without doubt due to the difference in the structure of the tegumentary systems of the two Reptiles; the naked skin of the Frog absorbing the gas much more rapidly than the scaly integument of the Serpent.

In both animals (examined immediately after their death), the contractility of the muscular system had been destroyed. The heart was the last portion of the muscular system to yield to the effects of the poison; it continued to beat feebly for a short time.

The blood from all parts of the body was of a brilliant scarlet color, and coagulated into a dense, firm clot, which was unstable and dissolved again. After the dissolution of the fibrin, the blood-corpuscles settled to the bottom, and the serum above was perfectly clear and without any marked color. Under the microscope, the blood-corpuscles presented no unusual appearance when their broad surfaces were turned towards the eye; when, however, they were viewed edgeways, they appeared swollen, and the central nuclei were much less distinct than in their normal condition, being scarcely visible.

Acetic acid exerted its characteristic action, first rendering the blood-corpuscles dumb-bell or hour-glass in shape, when viewed edgeways, and then rendering the exterior cell-wall transparent, and bringing out clearly the nuclei. When the acetic acid was neutralized with diluted liquor potassa, the cell-walls were again brought into view. Concentrated liquor potassa dissolved the blood-corpuscles with no immediate change of color. In a few moments, however, the color changed to a darker red, and gradually assumed a brownish-yellow color, and became, as usual, ropy and viscid.

Vigorous streams of carbonic acid and oxygen gases, passed through separate and the same portions of blood, produced no change whatever in the scarlet color or form of the blood-corpuscles.

Portions of this blood were kept for several weeks, and they still retained their scarlet color, and did not undergo putrefaction.

These reactions show that the change in the color of the blood was due, not to an alteration of the forms of the blood-corpuscles, but to a permanent chemical change of their coloring matter. Another effect of the carbonic oxide gas was to render the fibrin unstable.

This gas arrests oxidation, and the rapidity of its action shows the great im-

portance of this process. The existence of the vital force, and the performance of the functions of the organs and apparatus of the system, are incompatible with the sudden arrest of the chemical changes and metamorphoses of the elements of the solids and fluids. If, however, the process of oxidation be slowly stopped, by a gradual diminution of the temperature of cold-blooded animals, the existence of the vital force is not destroyed, although all the vital, physical, and mechanical functions are suspended.

Hydrogen Gas.

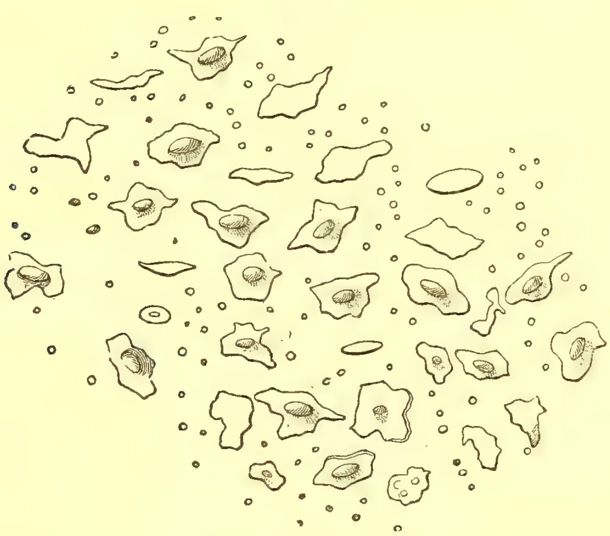
A Yellow-bellied Terrapin (*Emys serrata*), which had been placed in a large receiver of hydrogen gas, died in ten hours.

The blood-corpuscles from all parts of the body presented an altered appearance, similar, in many instances, to that produced by carbonic acid gas. The simple exclusion of the oxygen of the atmosphere, by a harmless gas, produced remarkable alterations in the shape of the corpuscles.

The urine contained grape sugar.

Fig. 6 represents the appearance of the blood-corpuscles of this *Emys serrata*, after it had been confined in hydrogen gas for ten hours.

FIG. 6.



Blood-corpuscles of a Yellow-bellied Terrapin (*Emys serrata*) which had been destroyed in hydrogen gas.

Complete Deprivation of Air.

Ligatures were passed around the tracheas of Yellow-bellied Terrapins (*Emys serrata*) and Salt-water Terrapins (*Emys terrapin*), which had been deprived of food and drink for several weeks, and then transferred to tubs of water, and abundantly supplied with vegetable food. The access of air to the lungs was thus completely cut off.

These Chelonians gave signs of muscular contractility for twelve to twenty hours. In one instance, the stomach and intestines became greatly distended with gas, which consisted partly of carbonic acid.

In all cases, the blood examined after death was of a blackish-red color, and much darker than that of Reptiles in its normal condition. It coagulated when abstracted.

The blood-corpuscles had undergone important modifications. Many of them were shrunken, contorted and contracted; others were swollen, assuming the forms of spheroids, and cubes, and irregular ovoids. The nuclei, which were rendered distinct by the action of acetic acid, in many cases presented corresponding changes. Many of the colorless corpuscles appeared altered in shape.

A stream of oxygen gas, passed through the blood, did not change its color, neither were the forms of the blood-corpuscles altered.

In every instance the urine of these terrapins contained grape sugar.

Figure 7 represents the blood-corpuscles of these terrapins, after they had been deprived of air by a ligature around their windpipes.

Fig. 7.

Blood-corpuscles of salt-water Terrapins (*Emys terrapin*) and fresh-water Terrapins (*Emys serrata*), which had been deprived of air by ligatures around their necks.

We will next consider the fibrin and fixed saline constituents of the blood of animals, in its normal condition.

Table of the Fibrin in 1000 *parts of the Blood of Animals.*

Name of observer.	Name of animal.	Fibrin in 1000 parts of blood.
Jos. Jones	*Trygon sabina* (Stingray)	unstable
"	*Zygæna malleus* (Hammerhead Shark) . . .	unstable
"	*Lepisosteus osseus* (Garfish)	unstable
J. F. Simon . . .	Carp	unstable
"	Tench	unstable
Jos. Jones	*Rana catesbæana* (Bullfrog)	unstable
J. F. Simon . . .	*Bufo variabilis*	unstable
Jos. Jones	*Heterodon niger* (Black Viper)	2.16
"	*Psammophis flagelliformis* (Coachwhip Snake) .	1.88
"	*Coluber constrictor* (Black Snake) . . .	5.06
"	*Chelonia caretta* (Loggerhead Turtle) . . .	2.61
"	*Chelonura serpentina* (Snapping Turtle) . .	0.35
"	*Emys terrapin* (Salt-water Terrapin) . . .	4.15
"	*Emys reticulata* (Chicken Terrapin) . . .	2.51
"	*Emys serrata* (Yellow-bellied Terrapin) . .	1.04
"	*Testudo polyphemus* (Gopher)	5.73
"	*Alligator Mississippiensis* (Alligator) . . .	3.07
Nasse	Goose	3.46
"	Hen	4.67
Jos. Jones	*Ardea nycticorax* (Heron)	2.20
"	*Syrnium nebulosum* (Barred Owl) . . .	4.69
"	*Cathartes atratus* (Black Turkey-Buzzard) . .	0.41
Andral, Gavarret, and Delafond	17 Horses — Mean	4.0
	17 Horses — Maximum	5.0
	17 Horses — Minimum	3.0
Nasse	Horse	2.41
Andral, Gavarret, and Delafond	14 Cattle — Mean	3.7
	14 Cattle — Maximum	4.4
	14 Cattle — Minimum	3.0
Nasse	Ox	3.62
Andral, Gavarret, and Delafond	19 Sheep — Mean	3.1
	19 Sheep — Maximum	3.8
	19 Sheep — Minimum	2.6
" " "	6 Swine — Mean	4.6
	6 Swine — Maximum	5.0
	6 Swine — Minimum	4.1
Nasse	Swine	3.95
"	Goat	3.90
Andral, Gavarret, and Delafond	16 Dogs — Mean	2.1
	16 Dogs — Maximum	3.5
	16 Dogs — Minimum	1.6
Nasse	Dog	1.93
Jos. Jones	Common Cur-Dog	3.04
"	Common Cur-Dog	3.15
Nasse	Cat	2.42

From this table we learn that the fibrin constitutes a remarkable index of the vital, organic, and intellectual endowments of animals.

In the whole of the invertebrate kingdom it is absent, except in a few of the most highly organized, in which its presence is accompanied by a corresponding improvement of the cerebro-spinal system, and all the organs.

In the lowest orders of the Vertebrata, as Fishes and Batrachians, it is soft, unstable, and readily convertible into albumen.

In the Ophidians and Chelonians, although it is stable and does not dissolve, still its structure is soft and inconsistent, and resembles, in many respects, the fibrin which is formed when the vital forces of warm-blooded animals have been exhausted by copious and continued bleedings.

Here we have a beautiful demonstration of the fact, that the animal kingdom is

constructed upon one great plan. Pathological conditions of the most highly organized animals are found to exist as the normal and permanent conditions of those placed below in the scale of creation. If the forces of a warm-blooded animal be reduced, it presents a condition in many respects similar to that of a cold-blooded animal. We will illustrate this by one other example.

Warm-blooded animals, in health, are able to maintain their temperature at a fixed standard, regardless of that of the surrounding medium. As the surrounding temperature descends, the efforts of nature to sustain a definite degree of heat increase. If, however, the forces of the animal economy be impaired, the efforts of nature are no longer sufficient to keep the body heated to the normal degree, and gradually the body assumes the temperature of the surrounding medium. The intellect and all the organic forces become torpid, the chemical actions cease, or are performed in a feeble or perverted manner; and, finally, the once active and warm-blooded animal is reduced to the condition of a sluggish cold-blooded one.

This table also apparently shows that the fibrin is one of the most variable of all the constituents of the blood. This, however, probably arises in great measure from imperfections in our methods of analysis.

We shall next consider the amount of fixed saline constituents in the blood of different animals.

Table of the Fixed Saline Constituents in the Blood of different Animals.

Name of observer.	Name of animal.	Fixed saline constituents in 1000 parts of blood.	
C. Schmidt	*Anodonta cygnea* (Pond Mussel)	0.256	Invertebrate animals.
Harless and Bibra	*Helix pomatia* (Shell Snail)	6.12	
Bibra	Ascidians and Cephalopods	2.63	
Genth	*Limulus Cyclops*	3.327	
Jos. Jones	*Trygon sabina* (Stingray)	14.70	Salt-water Fishes and Reptiles.
"	*Zygæna malleus* (Hammerhead Shark)	8.36	
"	*Lepisosteus osseus* (Garfish)	10.27	
"	*Emys terrapin* (Salt-water terrapin)	10.74	
"	*Alligator Mississippiensis* (Alligator)	8.65	
"	*Chelonia caretta* (Loggerhead Turtle)	3.58	
"	*Rana catesbæana* (Bullfrog)	5.78	Fresh-water Reptiles.
"	*Chelonura serpentina* (Snapping Turtle)	4.39	
"	*Emys serrata* (Yellow-bellied Terrapin)	5.22	
"	*Emys reticulata* (Chicken Terrapin)	7.79	
"	*Heterodon platyrhinos* (Hog-nose Viper)	13.47	Land Reptiles.
"	*Heterodon niger* (Black Viper)	7.04	
"	*Psammophis flagelliformis* (Coach-whip Snake)	5.57	
"	*Coluber constrictor* (Black Snake)	8.77	
"	*Testudo polyphemus* (Gopher)	5.83	
"	*Cathartes atratus* (Black Buzzard)	8.33	Birds.
"	*Ardea nycticorax* (Heron)	6 59	
"	*Syrnium nebulosum* (Owl)	8.06	
Nasse	Goose	7.92	
"	Hen	8.79	
"	Sheep	7.76	Mammalia.
"	Horse	7.85	
"	Ox	6.95	
"	Calf	7.87	
"	Goat	7.84	
"	Rabbit	6.28	
"	Cat	7.84	
"	Dog	7.33	
Jos. Jones	Common Cur-Dog	6.04	
"	Common Cur-Dog	6.11	

From this table we learn that the proportion of fixed saline constituents in the blood, is remarkably uniform throughout the whole animal kingdom. This fact demonstrates their importance.

In the invertebrata they exist in larger amount relatively to that of the organic constituents of the blood than in vertebrate animals. Thus, in the blood of the Esculent Snail (*Helix pomatia*) there were, according to Harless and Bibra, 6.12 parts of mineral, and only 8.39 parts of organic substances. In the blood of Ascidians and Cephalopods, Bibra found 4.7 parts of organic, and 2.63 parts of mineral substances. When we consider the constitution of the shells of these animals, it is not wonderful that the blood should contain so large a proportion of mineral substances. Schmidt found the albumen of the blood of the Pond Mussel (*Anodonta cygnea*) combined with lime. This fact shows that these mineral bodies are chemically combined with the organic constituents of their bodies.

Amongst vertebrate animals, we find the largest amount of mineral constituents in the blood of Fishes and Reptiles inhabiting the salt water. The only exception to this rule, was found in the blood of the Loggerhead Turtle (*Chelonia caretta*), which had been kept, for forty-eight hours previous to this analysis, in a tub of fresh water. It is possible that an interchange may have taken place between the exterior water and the salts held in solution in the blood. The blood of the Hog-nose Viper (*Heterodon platyrhinos*) yielded a larger amount of ash than that of any other animal. This is accounted for by the fact that the reptile had been starved for a length of time, and the blood was in a concentrated condition. The Alligator is classed amongst the salt-water Reptiles, because it had resided in a small salt-water stream, in a salt marsh. This reptile inhabits, most generally, the brackish and fresh-water rivers, lakes, swamps, and rice-fields.

That the fixed saline constituents are absolutely necessary, not only for the formation of the different structures, but also for the maintenance of life itself, was conclusively demonstrated by a series of experiments performed in France. It was found that when animals were fed upon grain, from which only one element (phosphate of lime) was abstracted, they rapidly lost their forces, and died in the course of a few weeks.

Having completed the study of the blood in its normal condition, we are now prepared to investigate the effects of starvation and thirst.

CHAPTER III.

PHYSICAL AND CHEMICAL CHANGES OF THE SOLIDS AND FLUIDS OF COLD AND WARM-BLOODED ANIMALS, WHEN DEPRIVED OF FOOD AND DRINK.

Series I.—Effects of Starvation and Thirst upon the Fluids and Solids of Alligators (*Alligator Mississippiensis*).

21. *Blood of a small female Alligator, in its normal condition.*

Although this reptile had been shot for half an hour, the blood flowed from its arteries in rapid streams, and twelve fluidounces were collected without any special care.

This alligator had been well fed, and was in good condition; the abdominal cavity, especially in the region of the kidneys, was lined with fat.

Specific gravity of defibrinated blood	1046.
Solid constituents in 1000 parts of blood	176.14
" " " serum	90.80
" in serum of 1000 parts of blood	82.05
Water in 1000 parts of blood	823.86
" " serum	909.20

1000 parts of blood contained—

Water	823.86
Blood-corpuscles (dried organic constituents)	86.39
Albumen	63.75
Fibrin	3.07
Water extract and alcohol extract	9.26
Fatty constituents	5.02
Fixed saline constituents	8.65

1000 parts of blood contained—

Moist blood-corpuscles	364.08	Water	273.06
		Solid constituents	91.02
Liquor sanguinis	635.92	Water	550.80
		Solid constituents	85.12

22. *Blood of a small male Alligator.* April 4.

The subject of these investigations was kept for two weeks and a half, without food or drink. It lived in the same stream with the one used in the preceding analysis, and was in all probability its mate.

This reptile was captured in a novel manner. The ear of the Alligator is provided with a lid which completely covers the *meatus auditorius externus.* When this lid is closed, it is impossible to discover the position of the ear without close

inspection. When I fired at the reptile, this lid was raised, and a single small buck-shot passed into the *meatus auditorius externus*, glanced against the bones, and ranging forwards, lodged against the eyeball. The lid was immediately shut down, and remained thus during his confinement. The only evidence of any injury, was a few drops of blood issuing from the corner of his eye; and, although I saw him every day, the true nature of the wound was not ascertained until after his death. The injury was productive of no serious consequences whatever, and only produced a temporary paralysis, just long enough to effect his capture.

In confinement he was exceedingly fierce, when disturbed, opening his jaws and drawing in his breath, making a hissing noise, and swelling out his body, like some Ophidians. When touched or approached, he would throw his head and body completely around—his head occupying the position of his tail. Simultaneously with this movement, the tail was brought violently towards the distended jaws.

During two and a half weeks, he passed no fecal matters, and discharged his urine but once, in quantity about two fluidounces. The urine consisted of a fluid, and a solid, chalk-like portion, composed of innumerable globules of the urate of ammonia.

The blood flowed slowly, and was much less in quantity than that of the female alligator, examined in its normal condition. It coagulated into a dense, coherent clot, immediately after its abstraction from the body.

Specific gravity of defibrinated blood	1056.
Solid constituents in 1000 parts of blood	196.57
" " " serum	90.80
" in serum of 1000 parts of blood	80.24
Water in 1000 parts of blood	803.43
" " serum	909.20

1000 parts of blood contained—

Water	803.43
Blood-corpuscles (dried organic constituents)	106.80
Albumen, and water extractive	74.02
Fibrin	3.41
Fatty constituents and alcoholic extract	2.00
Fixed saline constituents	10.34

1000 parts of blood contained—

Moist blood-corpuscles	451.68	Water	338.76
		Solid constituents	112.92
Liquor sanguinis	548.32	Water	464.67
		Solid constituents	83.65

By comparing the results obtained from the female alligator, in a normal condition, with those obtained from its mate—which had been kept without food and drink for seventeen and a half days—we see that the most obvious effects of starvation and thirst were the diminution of its blood and the consumption of the fat deposited in its tissues. In the normal subject, twelve fluidounces of blood were, with ease, obtained; whilst from the one deprived of food and drink for seventeen and a half days, not more than one-third of this amount could with difficulty be collected. The changes in the relative amounts of the different constituents of the blood will be seen in the following tables:—

Specific Gravities, Water, and Solid Constituents of the Blood.

	Specific gravity of blood.	Water in 1000 parts of blood.	Water in 1000 parts of serum.	Solid constituents in 1000 parts of blood.	Solid constituents in 1000 parts of serum.	Solid constituents in serum of 1000 parts of blood.
Alligator not starved . .	10.46	823.86	909.20	176.14	90.80	82.05
Alligator starved . . .	10.56	803.43	909.20	196.57	90.80	80.24

Moist Blood-Corpuscles and Liquor Sanguinis in 1000 *parts of Blood.*

	Moist blood-corpuscles.	Water in moist blood-corpuscles.	Solid constituents in moist blood-corpuscles.	Liquor sanguinis.	Water in liquor sanguinis.	Solid constituents in liquor sanguinis.
Alligator not starved . .	364.08	273.06	91.02	635.92	550.80	85.12
Alligator starved . . .	451.68	338.76	112.92	548.32	464.67	83.65

Organic and Inorganic Constituents in 1000 *parts of Blood.*

	Water in 1000 parts of blood.	Dry organic constituents of the blood-corpuscles in 1000 parts of blood.	Albumen and extractive matters.	Fat.	Fibrin.	Fixed saline constituents.
Alligator not starved . .	823.86	86.39	73.01	5.02	3.07	8.65
Alligator starved . . .	803.43	106.80	74.02	2.00	3.41	10.34

If we assume that the blood of both alligators had originally the same relative amounts of organic and inorganic constituents, we may note the following changes during abstinence from food and drink:—

The amount of water in the blood was diminished, and the solid constituents relatively, not absolutely, increased.

The number of blood-corpuscles in 1000 parts of blood had increased, whilst in the whole amount of blood originally possessed by the animal they had diminished.

The relative amount of solid constituents in the serum of 1000 parts of blood, had neither increased nor diminished; whilst two-thirds of the amount originally existing in the blood of the reptile had been consumed. Therefore, the constituents of the serum wasted more rapidly than the blood-corpuscles.

The fats and extractive matters were diminished.

The amount of fibrin was relatively increased from 3.07 to 3.41. Its relative increment did not correspond with the concentration of the blood. It was consumed more rapidly than the blood-corpuscles, and not so rapidly as the solid constituents of the serum.

The relative increase in the fixed saline constituents correspond, in part, with the concentration of the blood.

In comparing the blood of one animal with that of another, we determine the influences of starvation and thirst, relatively and not absolutely. If our facts and conclusions were drawn from a few isolated instances, we would be liable to error.

Sources of error, however, have been avoided, as far as possible, by first investigating the blood of cold-blooded animals in a normal state, and then performing an extensive series of experiments upon the effects of a deprivation of food and water. It would have, undoubtedly, added to the accuracy of these experiments, if we could have noted the changes, from time to time, going on in the blood of the same animal. This would have been practicable with the alligators, if they could have been obtained alive. These animals are found in our swamps, marshes, lagoons, and rivers. Their place of habitation is often of difficult access, and very unhealthy in the summer season to the white man, and the reptiles themselves are shy, and can therefore but rarely be obtained in a living state. A shot, from a rifle, in the head (the only vital part), destroys the life, and before they can be carried home, the blood is unfit for analytical examination. In a morning's hunt I have mortally wounded five or six without obtaining a single one, for they all sank in deep water.

With reference to the Terrapins, they are generally so small that the extraction of the amount of blood requisite for only two analyses, would materially affect the final result. We have, accordingly, been compelled to choose between two evils.

By multiplying these observations, as accurate results, we think, have been obtained as if the same cold-blooded animal had been used during the investigation.

We hope that those who may have occasion to follow us in our researches, will make due allowance for the difficulties with which we have had to contend.

SERIES II.—EFFECTS OF STARVATION AND THIRST UPON THE BLOOD OF THE SALT-WATER TERRAPINS (*Emys terrapin*).

23. Blood of an *Emys terrapin,* in a normal condition, having been captured only twelve hours. July 3.

The serum was of a golden color, resembling that of the *Emys serrata*, *Emys reticulata,* and *Cathartes atratus.*

Amount of blood obtained, about 1000 grains.

Solid constituents in 1000 parts of blood	154.72
" " " " serum	43.83
" " in serum of 1000 parts of blood	38.75
Water in 1000 parts of blood	845.28
" " serum	956.17

1000 parts of blood contained—

Water	845.28
Blood-corpuscles (dried organic constituents)	103.82
Albumen, fatty and extractive matter	36.01
Fibrin	4.15
Fixed saline constituents	10.74

1000 parts of blood contained—

Moist blood-corpuscles	447.28	Water	335.46
		Solid constituents	111.82
Liquor sanguinis	552.72	Water	509.82
		Solid constituents	42.90

24. Blood of a Salt-water Terrapin (*Emys terrapin*), which had been kept without food and drink for forty days. July 23.

Weight, June 16	14.285 grains.
" July 23	11.400 "

In thirty-eight days this terrapin had lost 2.885 grains, a little more than one-fifth of its whole weight.

The amount of blood obtained was not more than one-third as much as that procured from terrapins, a short time after their removal from the water.

The blood coagulated rapidly, especially the portions drawn last, which coagulated almost as soon as they reached the bottom of the vessel.

The serum was of a bright, golden color. It was difficult to obtain any amount of it perfectly free from the coloring matter of the blood-corpuscles. When treated with sulphuric acid and a gentle heat, the characteristic odor of the animal was developed.

The blood-corpuscles presented no unusual appearance under the microscope, and gave the characteristic reactions with chemical reagents. This fact proves that a free interchange between the exterior liquor sanguinis and the internal fluid contents of the blood-corpuscles must have been carried on without any intermission.

This animal was probably enfeebled, by long fasting, to a less extent than other animals of this class, because it had deposited eggs only a short time before its capture.

Amount of blood obtained, about 400 grains.

Solid constituents in 1000 parts of blood	199.41
" " " serum	79.50
" in serum of 1000 parts of blood	69.15
Water in 1000 parts of blood	800.59
" " serum	920.50

1000 parts of blood contained—

Water	800.59
Blood-corpuscles (dried organic constituents)	118.56
Albumen and extractive matter	64.85
Fibrin	5.26
Fixed saline constituents	10.74

1000 parts of blood contained—

Moist blood-corpuscles	500.00	Water	375.00
		Solid constituents	125.00
Liquor sanguinis	500.00	Water	425.59
		Solid constituents	74.41

400 parts of blood contained—

Water	320.23
Blood-corpuscles (dried organic constituents)	47.43
Albumen, fatty and extractive matter	25.94
Fibrin	2.11
Fixed saline constituents	4.29
Solid constituents in 400 grains of blood	79.76
" in serum of 400 grains of blood	27.66

400 grains of blood contained—

Moist blood-corpuscles	200.00	Water	150.00
		Solid constituents	50.00
Liquor sanguinis	200.00	Water	170.23
		Solid constituents	29.77

If this terrapin had originally an equal amount of blood of the same chemical constitution with that of the terrapin in the normal state, used in the preceding analysis, then it had lost, during forty days, 600 grains of blood, which had the following composition:—

600 grains of blood, consumed during starvation, contained—

Water	525.05
Blood-corpuscles (dried organic constituents)	56.39
Albumen, fatty and extractive matter	10.07
Fibrin	2.04
Fixed saline constituents	6.45
Solid constituents in 600 grains of blood	74.95
" " in serum of 600 grains of blood	11.09

600 grains of blood contained—

Moist blood-corpuscles	247.28	Water	185.46
		Solid constituents	61.82
Liquor sanguinis	352.72	Water	339.59
		Solid constituents	13.13

25. Blood of a female Salt-water Terrapin (*Emys terrapin*), which had been kept without food and drink for fifty-seven days.

Weight of terrapin, June 21	12.280 grains.
" " August 16	9.255 "
Loss of weight during fifty-six days	3.025 "

In fifty-six days this Chelonian had lost one-fourth of its original weight. The loss each hour during its starvation, was $\frac{1}{5458}$ of the original weight of its body.

This terrapin had just deposited its eggs when captured, and this will account for its living so great a length of time without food or drink.

The female terrapins that were captured before their eggs were deposited, refused to lay, in confinement, became feeble, and died in the course of two or three weeks. This was, without doubt, the result of the anxiety and irritation, occasioned and kept up by the eggs within them.

The blood-corpuscles, under the microscope, presented no unusual appearance, showing that a free interchange between the liquor sanguinis and their contents had been carried on continuously.

Amount of blood obtained	200 grains.
Probable amount of blood consumed	800 "
Solid constituents in 1000 parts of blood	255.22
" " " serum	111.96
" in serum of 1000 parts of blood	92.82
Water in 1000 parts of blood	744.78
" " serum	888.04

1000 parts of blood contained—

Water	744.78
Blood corpuscles (dried organic constituents)	156.96
Albumen, fatty and extractive matter	90.87
Fibrin	1.85
Fixed saline constituents	5.52

1000 parts of blood contained—

Moist blood-corpuscles	642.20	Water	481.65
		Solid constituents	160.55
Liquor sanguinis	357.80	Water	263.13
		Solid constituents	94.67

The number of blood-corpuscles appears to be very great, but it is so only in appearance and not in reality; for, the amount of blood in the Chelonian is very small, and the blood-corpuscles correspondingly few in number. The whole amount of blood, obtained with great care, did not exceed 200 grains.

200 grains contained—

Water	148.96
Blood-corpuscles (dried organic constituents)	31.39
Albumen and extractive matter	18.17
Fibrin	.37
Fixed saline constituents	1.11
Solid constituents in 200 grains of blood	51.04
" " in serum of 200 grains of blood	18.56

200 grains of blood contained—

Moist blood-corpuscles	128.44	Water	96.33
		Solid constituents	32.11
Liquor sanguinis	71.56	Water	52.63
		Solid constituents	18.93

If the starved terrapin, and the one in a normal condition possessed originally equal quantities of blood, having the same chemical constitution, then the starved terrapin must have consumed, during fifty-seven days, 800 grains of blood, having the following constitution:—

Solid constituents in 800 grains of blood	103.68 grains.
" " in serum of 800 grains of blood	20.19 "

800 grains of blood contained—

Water	696.32
Blood-corpuscles (dried organic constituents)	72.43
Albumen, fatty and extractive matter	17.84
Fibrin	3.78
Fixed saline constituents	9.63

800 grains of blood contained—

Moist blood-corpuscles	318.84	Water	239.13
		Solid constituents	79.71
Liquor sanguinis	481.16	Water	457.19
		Solid constituents	23.97

In noting the changes of the constituents of the blood of the *Emys terrapin* during starvation, we might be led into error if the relative quantities of the different con-

stituents in 1000 parts of blood, alone, were considered; for the blood-corpuscles and all the organic and inorganic constituents in this case would appear to have increased rather than diminished during starvation. A correct view of the effects of starvation can only be obtained by ascertaining the absolute amounts of blood and its constituents existing in these reptiles during different lengths of starvation.

By comparing these results with the quantity and constitution of blood in animals in a normal condition, not deprived of food or drink, we can calculate, approximately, the amount of blood and its various constituents that have been consumed during starvation, to supply the wastes of the tissues and keep up the animal temperature.

The following tables give a condensed view of the effects of starvation. They must not be considered absolutely correct, but only as an approximation to the truth.

It would be impossible to determine these changes with absolute accuracy, because differences in the amount and constitution of the blood always exist in different individuals.

I.—*Tables showing the Changes in the Relative Amounts of the Organic and Inorganic Constituents of the Blood of Salt-water Terrapins* (Emys terrapin), *during different periods of Starvation and Thirst. The numbers represent the amount existing in* 1000 *parts of blood. The changes, therefore, are relative, and not absolute.*

WATER AND SOLID MATTERS OF BLOOD AND SERUM.

	Period of starvation and thirst.	Water in 1000 parts of blood.	Water in 1000 parts of serum.	Solid constituents in 1000 parts of blood.	Solid constituents in 1000 parts of serum.	Solid constituents in serum of 1000 parts of blood.
1st female terrapin	12 hours	845.28	956.17	154.72	43.83	38.75
2d " "	40 days	800.59	920.50	199.41	79.50	69.15
3d " "	57 "	744.78	888.04	255.22	111.96	92.82

CONSTITUENTS OF 1000 PARTS OF BLOOD.

	Period of starvation and thirst.	Water.	Blood-corpuscles (dried organic constituents).	Albumen, fatty and extractive matters.	Fibrin.	Fixed saline constituents.
1st female terrapin	12 hours	845.28	103.82	36.01	4.15	10.74
2d " "	40 days	800.59	118.56	64.85	5.26	10.74
3d " "	57 "	744.48	156.98	90.87	1.85	5.52

MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

	Period of starvation and thirst.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
		Moist blood-corpuscles in 1000 parts of blood.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis in 1000 parts of blood.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
1st female terrapin	12 hours	447.28	335.46	111.82	552.72	509.82	42.90
2d " "	40 days	500.00	375.00	125.00	500.00	425.59	74.41
3d " "	57 "	642.20	481.65	160.55	357.80	263.13	94.67

II.—*Tables showing the Actual Amounts of Blood and its Constituents in Salt-water Terrapins, during different periods of Starvation and Thirst.*

WATER AND SOLID CONSTITUENTS OF BLOOD AND SERUM.

	Period of starvation and thirst.	Amount of blood obtained.	Water of blood.	Solid constituents of blood.	Solid constituents of serum.
1st female terrapin	12 hours	1000 grains	845.28	154.72	38.75
2d " "	40 days	400 "	320.23	79.76	27.66
3d " "	57 "	200 "	148.96	51.04	18.56

CONSTITUENTS OF BLOOD.

	Period of starvation and thirst.	Water.	Blood-corpuscles (dried organic constituents).	Albumen and extractive matter.	Fibrin.	Fixed saline constituents.
1st female terrapin	12 hours	845.28	103.82	36.01	4.15	10.74
2d " "	40 days	320.23	47.43	25.95	2.11	4.29
3d " "	57 "	148.96	31.40	18.17	.37	1.10

MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

		MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
	Period of starvation and thirst.	Moist blood-corpuscles.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
1st female terrapin	12 hours	447.28	335.46	111.82	552.72	509.82	42.90
2d " "	40 days	200.00	150.00	50.00	200.00	170.23	29.77
3d " "	57 "	128.44	96.33	32.11	71.56	52.63	18.93

III.—*Table of the Actual Loss of Weight and Blood, by the Emys Terrapin, during different periods of Starvation and Thirst, in Troy grains.*

	Period of starvation and thirst.	Weight before starvation.	Weight after starvation.	Loss of weight during starvation.	Loss of weight compared to weight of body.	Loss of weight each hour.	Loss of weight per hour, compared to weight of body.	Loss of blood during starvation.
		Grains.	Grains.	Grains.		Grains.		Grains.
2d female terrapin	38 days	14,285	11,400	2,885	$\frac{1}{5}$th	3.317	$\frac{1}{4366}$th	600.
3d " "	56 "	12,280	9,255	3,025	$\frac{1}{4}$th	2.25	$\frac{1}{5458}$th	800.

IV.—*Tables showing the Actual Losses of Blood and its Constituents by Emys terrapin, during different periods of Starvation and Thirst.*

WATER AND SOLID CONSTITUENTS OF BLOOD AND SERUM.

	Period of starvation and thirst.	Amount of blood lost.	Water of blood.	Solid constituents of blood.	Solid constituents of serum.
		Grains.	Grains.	Grains.	Grains.
2d female terrapin	40 days	600	525.05	74.95	11.09
3d " "	57 "	800	696.32	103.68	20.19

CONSTITUENTS OF BLOOD.

	Period of starvation and thirst.	Amount of water lost.	Blood-corpuscles.	Albumen and extractive matters.	Fibrin.	Fixed saline constituents.
		Grains.	Grains.	Grains.	Grains.	Grains.
2d female terrapin	40 days	525.05	56.39	10.07	2.04	6.45
3d " "	57 "	696.32	72.42	17.84	3.78	9.63

MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

	Period of starvation and thirst.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
		Moist blood-corpuscles.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
		Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
2d female terrapin	40 days	247.28	185.46	61.82	352.72	339.59	13.13
3d " "	57 "	318.84	239.13	79.71	481.16	457.19	23.97

These tables show that, during starvation, the water wasted more rapidly than any of the other constituents of the blood, which became more and more concentrated as starvation advanced, and hence the apparent increase in its solid constituents in 1000 parts. The blood-corpuscles wasted as well as the albumen, fibrin, and fixed saline constituents. This fact proves that the blood-corpuscles have important offices to fulfil, in supplying the tissues and organs with nutriment, and replacing the organic and inorganic constituents thrown off and consumed.

SERIES III.—EFFECTS OF STARVATION AND THIRST UPON THE FLUIDS AND SOLIDS OF YELLOW-BELLIED TERRAPINS (*Emys serrata*).

26. Blood of a Female *Emys serrata*, which had been kept without food or drink for three and a half days. May 26th.

Weight of terrapin, May 25th	33.417 grains.
" " twelve hours afterwards	33.258 "
Loss of weight in twelve hours	159 "

In twelve hours it had lost $\frac{1}{210}$th of its whole weight, or $\frac{1}{2520}$th per hour.

The portions of blood drawn first coagulated much more slowly than those drawn last. The first portion drawn, coagulated so slowly that the corpuscles sank to the bottom of the vessel, and a transparent clot was left above. This takes place in a less degree in the blood of females during pregnancy, in that of puerperal fever, acute rheumatism, and inflammations generally.

The serum was of a bright golden color; and, when kept for several hours, partially coagulated.

Specific gravity of the blood	1026.5
" " " serum	1013.7
Solid constituents in 1000 parts of blood	124.59
" " " serum	43.03
" in serum of 1000 parts of blood	39.36
Water in 1000 parts of blood	875.41
" " serum	956.97

1000 parts of blood contained—

Water	875.41
Blood-corpuscles	80.67
Albumen, fatty and extractive matter	37.66
Fibrin	1.04
Fixed saline constituents	5.22

1000 parts of blood contained—

Moist blood-corpuscles	336.76	Water	252.57
		Solid constituents	84.19
Liquor sanguinis	663.24	Water	622.84
		Solid constituents	40.40

Amount of blood obtained from this terrapin, 2000 grains.

Solid constituents in 2000 grains of blood	249.18
" " " serum	86.06
" in serum of 2000 grains of blood	78.72
Water in 2000 grains of blood	1750.82
" " serum	1913.94

2000 grains of blood contained—

Water	1750.82
Blood-corpuscles (dried organic constituents)	161.34
Albumen, fatty and extractive matter	75.32
Fibrin	2.08
Fixed saline constituents	10.44

2000 grains contained—

Moist blood-corpuscles	673.52	Water	505.14
		Solid constituents	168.38
Liquor sanguinis	1326.48	Water	1245.68
		Solid constituents	80.80

27. Blood of a female Yellow-belly Terrapin (*Emys serrata*), which had been kept without food or drink for seventeen days. June 8.

Weight, May 25	20.873 grains.
" June 8	18.756 "
Loss of weight in fourteen days	2.117 "

In fourteen days this Chelonian lost a little more than one-tenth of its whole weight.

Specific gravity of its blood	1040.5
Solid constituents in 1000 parts of blood	178.11
" " " serum	64.51
" in serum of 1000 parts of blood	56.68
Water in 1000 parts of blood	821.87
" " serum	935.49

1000 parts of blood contained—

Water	821.89
Blood-corpuscles (dried organic constituents)	115.75
Albumen, fatty and extractive matters	54.68
Fibrin	1.68
Fixed saline constituents	6.00

1000 parts of blood contained—

Moist blood-corpuscles	478.00	Water	358.25
		Solid constituents	119.75
Liquor sanguinis	522.00	Water	463.64
		Solid constituents	58.36

Amount of blood obtained, 800 grains.

Solid constituents in 800 grains of blood	142.55
" " serum of 800 grains of blood	45.26
Water in 800 grains of blood	657.51

800 grains of blood contained—

Water	657.51
Blood-corpuscles (dried organic constituents)	92.60
Albumen, fatty and extractive matter	43.75
Fibrin	1.34
Fixed saline constituents	4.80

800 grains contained—

Moist blood-corpuscles	383.80	Water	287.85
		Solid constituents	95.95
Liquor sanguinis	416.20	Water	369.60
		Solid constituents	46.60

By comparing the size and amount of blood of this terrapin with that of the terrapin in a normal condition, we obtain, as its probable loss of blood during seventeen days of starvation and thirst, 700 grains.

Solid constituents in 700 grains of blood consumed	44.40
Solid constituents in serum of 700 grains "	13.78
Water in 700 grains of blood	655.60

700 grains of blood contained—

Water	655.60
Blood-corpuscles (dried residue)	28.41
Albumen, fatty and extractive matter	12.74
Fibrin	0.22
Fixed saline constituents	3.03

700 grains of blood contained—

Moist blood-corpuscles	121.60	Water	91.20
		Solid constituents	30.40
Liquor sanguinis	578.40	Water	564.40
		Solid constituents	14.00

28. Blood of a Female Yellow-belly Terrapin (*Emys serrata*), which had been kept without food and drink for twenty-four days. May 23.

This terrapin was captured in the act of excavating a hole in which to deposit its eggs. As usual, they were not deposited during its captivity, but remained in the ovaries and oviducts for twenty-four days.

Solid constituents in 1000 parts of blood	206.28
" " " serum	88.67
" in serum of 1000 parts of blood	77.49
Water in 1000 parts of blood	793.72
" " serum	911.33

1000 parts of blood contained—

Water	793.72
Blood-corpuscles (dried organic constituents)	122.26
Albumen, fatty and extractive matter	74.49
Fibrin	1.68
Fixed saline constituents	7.85

Amount of blood obtained, 500 grains.

Solid constituents in 500 grains of blood	103.14
" " in serum of 500 grains of blood	38.74

500 grains of blood contained—

Water	396.88
Blood-corpuscles (dried organic constituents)	61.12
Albumen, fatty and extractive matter	37.24
Fibrin	0.84
Fixed saline constituents	3.92

1000 parts of blood contained—

Moist blood-corpuscles	508.44	Water	381.33
		Solid constituents	127.11
Liquor sanguinis	491.56	Water	412.39
		Solid constituents	79.17

500 grains of blood contained—

Moist blood-corpuscles	254.22	Water	190.67
		Solid constituents	63.55
Liquor sanguinis	245.78	Water	206.20
		Solid constituents	39.58

Probable amount of blood consumed during twenty-four days of starvation and thirst, 1500 grains.

Solid constituents in 1500 grains of blood	146.04
" " serum of 1500 grains of blood	39.98

1500 grains of blood contained—

Water	1353.96
Blood-corpuscles (dried organic constituents)	100.21
Albumen, fatty and extractive matter	38.08
Fibrin	1.24
Fixed saline constituents	6.52

1500 grains of blood contained—

Moist blood-corpuscles	419.28	Water	314.46
		Solid constituents	104.82
Liquor sanguinis	1080.72	Water	1039.50
		Solid constituents	41.22

29. Blood of Female Yellow-bellied Terrapin (*Emys serrata*), which had been kept without food or drink for twenty-six days.

Weight, May 26	34.155 grains.
" June 14	28.675 "
Loss of weight during twenty days	5.480 "

In twenty-six days this terrapin had lost from one-fourth to one-fifth of its whole weight. Loss of weight each hour, $11\frac{41}{100}$ grains, $= \frac{1}{2994}$th the original weight of its body.

This Chelonian was in a feeble state, and in all probability would not have lived many days.

When its tissues and organs were examined it was found that the yellow fat, which is so abundant in these animals, had disappeared, having been consumed for the maintenance of the animal function, and in the supply of the wastes of the tissues and organs. The destruction of the fat was observed to be one of the constant effects of starvation.

The amount of blood obtained was not more than one-half as much as that obtained from a much smaller terrapin, which was killed only a few days after its removal from the water.

Specific gravity of its blood	1043.
Solid constituents in 1000 parts of blood	198.66
" " " serum	95.48
" " serum of 1000 parts of blood	84.59
Water in 1000 parts of blood	801.34
" " serum	904.52

1000 parts of blood contained—

Water	801.34
Blood-corpuscles (dried organic constituents)	102.97
Albumen, fatty and extractive matter	80.09
Fibrin	4.15
Fixed saline constituents	11.45

1000 parts of blood contained—

Moist blood-corpuscles	439.68	Water	329.76
		Solid constituents	109.92
Liquor sanguinis	560.32	Water	471.58
		Solid constituents	88.74

Amount of blood obtained, 450 grains.

Solid constituents in 450 grains of blood	89.40
" " serum of 450 grains of blood	38.06

450 grains of blood contained—

Water	360.60
Blood-corpuscles (dried organic constituents)	46.34
Albumen, fatty and extractive matter	36.05
Fibrin	1.86
Fixed saline constituents	5.15

450 grains of blood contained—

Moist blood-corpuscles	197.92	Water	148.44
		Solid constituents	49.48
Liquor sanguinis	252.08	Water	212.16
		Solid constituents	39.92

Calculated amount of blood consumed during twenty-six days of starvation and thirst, 1550 grains.

Solid matter in 1550 grains of blood	159.78
" " serum of 1550 grains of blood	40.66

1550 grains of blood contained—

Water	1390.22
Blood-corpuscles (dried organic constituents)	115.00
Albumen, fatty and extractive matter	39.27
Fibrin	0.22
Fixed saline constituents	5.29

1550 grains of blood contained—

Moist blood-corpuscles	475.60	Water	356.70
		Solid constituents	118.90
Liquor sanguinis	1074.40	Water	1033.52
		Solid constituents	40.88

30. Blood of a Female *Emys serrata,* which had been kept without food and drink for thirty-one days.

Weight, May 25	41.086 grains.
" June 13	34.960 "
Loss of weight in twenty days	6.126 "

Loss of weight, each hour, $12\frac{76}{100}$ grains $= \frac{1}{2994}$th of the weight of its whole body. In thirty one days this terrapin lost from one-fourth to one-fifth of its whole weight.

On the day of the analysis the terrapin was found to be completely exhausted by starvation and thirst, and had scarcely strength to move its muscles.

Owing to the feeble state of its circulatory apparatus, and the rapidity of the

coagulation of its blood, only a small quantity was collected, insufficient for a complete analysis.

Solid constituents in 1000 parts of blood	222.22
Water in 1000 parts of blood	777.78

1000 parts of blood contained—

Water	777.78
Dried organic constituents	209.66
Fixed saline constituents	12.56

31. Blood of a Female *Emys serrata*, which was kept without food and drink for thirty-eight days.

Weight, May 25	38.540 grains.
" June 28	30.142 "
Loss of weight in thirty-four days	8.398 "

Loss of weight each hour $10\frac{29}{100}$ grains $= \frac{1}{3754}$th of the weight of the whole body. The loss of weight during thirty-eight days of starvation and thirst equalled one-fourth of the original weight of its body.

With the greatest care not more than two hundred grains of blood could be obtained, and the terrapin was weak from long fasting.

The fat of the body had in a great measure disappeared.

The clot formed in the blood was large, and the proportion of serum small. Not more than ten grains of serum could be obtained from $76\frac{65}{100}$ grains of blood, although it had stood for twelve hours. The clot showed little or no disposition to contract. The serum was colored red by the hæmatin of the blood.

The ovaries and oviducts contained twelve hard, and a multitude of soft yellow eggs.

Solid constituents in 1000 parts of blood	226.62
" " " serum	155.00
" " serum of 1000 parts of blood	141.86
Water in 1000 parts of blood	773.38
" " serum	845.00

1000 parts of blood contained—

Water	773.38
Blood-corpuscles (dried organic constituents)	72.91
Albumen, fatty and extractive matter	134.49
Fibrin	6.52
Fixed saline constituents	12.70

1000 parts of blood contained—

Moist blood-corpuscles	312.96	Water	234.72
		Solid constituents	78.24
Liquor sanguinis	687.04	Water	538.66
		Solid constituents	148.38

Amount of blood obtained, 200 grains.

Solid constituents in 200 grains of blood	45.32
" " serum of 200 grains of blood	28.37

200 grains of blood contained—

Water	154.68
Blood-corpuscles (dried organic residue)	14.58
Albumen, fatty and extractive matter	26.90
Fibrin	1.30
Fixed saline constituents	2.54

200 grains of blood contained—

Moist blood-corpuscles	62.60	Water	46.95
		Solid constituents	15.65
Liquor sanguinis	137.40	Water	107.73
		Solid constituents	29.67

Calculated amount of blood lost during thirty-eight days of starvation and thirst, 1800 grains.

Solid constituents in 1800 grains of blood	203.86
" " serum of 1800 grains of blood	62.69

1800 grains of blood contained—

Water	1596.14
Blood-corpuscles (dried organic constituents)	146.76
Albumen, fatty and extractive matter	48.42
Fibrin	0.78
Fixed saline constituents	7.90

1800 grains of blood contained—

Moist blood-corpuscles	561.56	Water	421.17
		Solid constituents	140.39
Liquor sanguinis	1238.44	Water	1174.97
		Solid constituents	63.47

32. Blood of a Male *Emys serrata*, which had been kept without food and drink for forty-nine days.

Weight, May 25	17.797 grains.
" June 9	14.400 "
Loss of weight in forty-five days	3.397 "

In forty-nine days this Chelonian lost one-fifth of its original weight. Loss of weight daily, $75\frac{44}{100}$ grains. Loss of weight hourly, $3\frac{14}{100}$ grains $= \frac{1}{5667}$th of original weight of its body.

All the terrapins (*Emys serrata*) heretofore examined were females, whose ovaries and oviducts contained from eight to twelve hard, and innumerable soft eggs.

The development and nourishment of these eggs consumed the blood, and, consequently, they sank more rapidly under starvation and thirst than this male, which had nothing to support but his own body.

The desire to deposit their eggs induced restlessness. They were continually endeavoring to escape from their confinement. This is in conformity with a law of the animal economy that the exertion of force is always attended by a simultaneous chemical and physical change of the organic elements of structure and nutrition. The amount of these changes corresponds with the force exerted.

The altered materials, which are no longer fit for nutrition or the formation of structure, are eliminated by the lungs and kidneys. The loss of weight by an animal during starvation and thirst should, therefore, correspond entirely with the physical and chemical changes of its organic elements, whatever may be the product of these changes, heat, nervous force, or muscular power.

This principle was strikingly verified by the results of these experiments.

The restless females lost from $\frac{1}{2728}$th to $\frac{1}{3313}$th of their weight hourly, whilst the quiet, composed, indolent male lost $\frac{1}{5667}$th of its weight hourly.

The waste of the blood and tissues was twice as rapid in the females, which corresponds to their greater exertions of muscular and nervous power.

Many of the females grew weak and died in two or three weeks, whilst this male remained active and fierce, apparently without any great diminution of strength and vitality during forty-nine days of starvation and thirst. That this endurance was not due to the peculiar constitution of this male, is proved by a reference to the experiments with the salt-water terrapins (*Emys terrapin*). Those that had deposited their eggs before their capture lived for fifty or sixty days, and their loss of weight corresponded with that of the male *Emys serrata.*

The amount of blood obtained without any difficulty, was 500 grains.

By comparing this with the amount obtained from females, under different periods of starvation and thirst, we see that the blood was consumed to a much less extent in the male.

Specific gravity of its blood	1048.7
Solid constituents in 1000 parts of blood	199.06
" " " serum	108.90
" in serum of 1000 parts of blood	97.88
Water in 1000 parts of blood	800.94
" " serum	891.10

1000 parts of blood contained—

Water	800.94
Blood-corpuscles (dried organic constituents)	92.29
Albumen, fatty and extractive matter	93.38
Fibrin	4.34
Fixed saline constituents	9.05

1000 parts of blood contained—

Moist blood-corpuscles	387.36	Water	290.52
		Solid constituents	96.84
Liquor sanguinis	612.64	Water	510.42
		Solid constituents	102.22

Solid constituents in 500 grains of blood	99.53
" serum of 500 grains of blood	48.94

500 grains of blood contained—

Water	400.47
Blood-corpuscles (dried organic constituents)	46.15
Albumen, fatty and extractive matter	46.69
Fibrin	2.17
Fixed saline constituents	4.52

500 grains of blood contained—

Moist blood-corpuscles	193.68	Water	145.26
		Solid constituents	48.42
Liquor sanguinis	306.32	Water	255.21
		Solid constituents	51.11

Calculated amount of blood consumed during 49 days of thirst and starvation. 1000 grains.

Solid constituents in 1000 grains of consumed blood	87.36
" serum of 1000 grains of consumed blood	10.10

1000 grains of consumed blood contained—

Water	912.64
Blood-corpuscles (dried organic constituents)	74.85
Albumen, fatty and extractive matter	9.80
Fibrin	.61
Fixed saline constituents	3.31

1000 grains of consumed blood contained—

Moist blood-corpuscles	309.04	Water	231.78
		Solid constituents	77.26
Liquor sanguinis	690.96	Water	680.86
		Solid constituents	10.10

The examination of the blood of this male *Emys serrata* completes the series of experiments upon the influence of starvation and thirst upon the constitution and amounts of blood in these Chelonians.

A comparison of these analyses with each other, shows that, in every instance, the water of the blood wasted more rapidly than the other constituents. The rapidity of this consumption of the water, and the consequent concentration of the blood, depended, therefore, upon the length of starvation, and the sex of the reptile.

In females whose ovaries and oviducts were filled with eggs, the anxiety to deposit these, conjoined with their development and nutrition, produced a more rapid consumption of the fat of the body and all the constituents of the blood than in the male. The effects of this anxiety and demand, for the nutrition and development of the eggs, was manifested also in a more rapid destruction of the nervous and vital forces.

The females became weak and exhausted, and several died in two or three weeks, whilst the males retained their usual activity and strength up to their destruction or removal to a tub of water, a period of time varying from three weeks to fifty days.

Tables showing the actual and relative amount of blood, also the actual losses of blood by Yellow-bellied Terrapins (*Emys serrata*), will be given in conjunction with others of a similar character, after the completion of our investigations upon the changes of the blood of different animals when deprived of all food and drink.

SERIES IV.—EFFECTS OF THIRST AND STARVATION UPON THE FLUIDS AND SOLIDS OF GOPHERS (*Testudo polyphemus*).

33. Blood of a male Gopher which had been captured for five days, and abundantly supplied with vegetable food.

Weight of this gopher, 45,500 grains.

When the arteries of the neck were cut, the blood flowed out in a jet, with considerable force, as from the severed artery of a warm-blooded animal.

The serum was of a light yellow color. It was not of such a golden color as that of the *Emys serrata*, or *Emys reticulata*, or *Cathartes atratus*. Heat and sulphuric acid developed in the serum the characteristic odor of the animal, which was similar to that of its urine, and the odor of grass contained in its colon resembled closely that of a sheep.

Amount of blood readily obtained	2500 grains.
Specific gravity of its blood	1030
" " serum	1018
Solid constituents in 1000 parts of blood	156.62
" " " serum	66.41
" in serum of 1000 parts of blood	60.00
Water in 1000 parts of blood	843.38
" " serum	933.59

1000 parts of blood contained—

Water	843.38
Blood-corpuscles (dried organic constituents)	87.28
Albumen, fatty and extractive matter	57.78
Fibrin	5.73
Fixed saline constituents	5.83

1000 parts of blood contained—

Moist blood-corpuscles	393.56	Water	302.67
		Solid constituents	90.89
Liquor sanguinis	606.44	Water	540.71
		Solid constituents	65.73

34. Blood of a male Gopher which was kept without food or drink for thirty days. July 11.

Weight, June 16	18.368 grains.
" " 28	17.919 "
" July 11	16.922 "
Loss of weight from June 16–28 (12 days)	449 "
" " " 28–July 11 (13 days)	997 "

In twenty-five days the loss of weight equalled 1446 grains. In twenty-five days this Gopher had lost $\frac{1}{12}$th of its original weight. Loss of weight each hour, grs. $2\frac{41}{100} = \frac{1}{7621}$th of the original weight of its body. Loss of weight each day—57.8 grains.

The increased loss of weight after June 28, was due to the passage of excrement at various times, and to the elevation of the temperature of the atmosphere. As

the temperature is elevated, the wastes of the tissues and chemical and physical changes in the organic molecules of cold-blooded animals are correspondingly increased. In a normal state, the converse of this proposition is true for warm-blooded animals. When, however, the forces are impaired, the warm-blooded animal is governed, in a great measure, by this law.

The serum resembled, in color and smell and relative amount, that of the former Gopher in a normal condition.

The amount of blood readily obtained, was more than 1000 grains. Although this Gopher had been deprived of food and drink for thirty days, still the blood did not appear to have been diminished in quantity. The reason of this will be seen in a few moments.

Specific gravity of its blood	1037
" " serum	1017
Solid constituents in 1000 parts of blood	147.23
" " " serum	61.16
" in serum of 1000 parts of blood	55.55
Water in 1000 parts of blood	852.77
" " serum	944.45

1000 parts of blood contained—

Water	852.77
Blood-corpuscles (dried organic constituents)	84.76
Albumen, fatty and extractive matter	53.17
Fibrin	2.99
Fixed saline constituents	6.31

1000 parts of blood contained—

Moist blood-corpuscles	355.76	Water	267.07
		Solid constituents	88.69
Liquor sanguinis	644.24	Water	585.70
		Solid constituents	58.54

By comparing this analysis with the preceding one, we see that the blood of the Gopher, unlike that of the carnivorous Chelonians, has remained unaltered, both in quantity and the relative proportions of its several ingredients, during a period of thirty days of starvation and thirst.

Upon an examination of its intestinal canal, and the exterior covering of its body, this remarkable power to resist the effects of starvation and thirst will be explained.

The colon of the Gopher enlarges into a receptacle, for food, thirty inches in length and three and a half to four inches in circumference (see Fig. 8). The contents of this consist of grass and leaves, resembling, both in odor and appearance, the contents of the stomach of herbivorous animals. After thirty days of starvation, the undigested vegetable contents of the intestinal canal amounted to 1460 grains.

The skin of the Gopher is almost completely covered with horny excrescences, which prevent all exhalation of water from the surface of the legs, head, and neck, and all those portions of the body not covered by the shell. Hence the loss of

water is very small in comparison with that of other terrapins. A large proportion of the weight of these animals, which is lost during starvation, is pure water.

These are wonderful and manifest provisions of the Great Architect, adapting this reptile for habitation in a barren, sandy country, where it is often impossible to obtain water, and where vegetation is scarce. The colon contains a store of vegetable food, which replaces the wastes of the blood and tissues during long seasons of drought. The vegetable matters of the colon also supply the place of the masses of fat found in the abdominal cavities of many Chelonians, Ophidians, and Saurians. We have never noticed this in the Gopher (*Testudo polyphemus*).

35. Blood of a male Gopher (*Testudo polyphemus*), which had been deprived of food and drink for fifty-one days. September 15.

Weight, August 9	21.485 grains.
" September 15	18.127 "
Loss of weight in thirty-seven days	3.358 "

Loss of weight daily, $90\frac{75}{100}$ grains. Loss of weight hourly, $\frac{1}{7621}$th of its original weight. During 51 days of thirst and starvation, this Gopher lost from one-fourth to one-fifth of its original weight.

During this time it discharged several excrements, but no urine. The Terrapins were usually kept in boxes, and examined daily, so that any discharge from the rectum or bladder could not pass unnoticed. During our experiments, not one of the Chelonians voided their urine, so that all these weights represent only the amounts of organic matters and water thrown off by the lungs and the surface of the body.

At the end of fifty-one days of starvation, this Gopher, with several others confined for a similar length of time, still possessed life and activity, and were capable of considerable muscular effort.

The quantity of blood had not diminished to any great extent.

Solid constituents in 1000 parts of blood	170.23
" " " serum	99.50
" in serum of 1000 parts of blood	91.68
Water in 1000 parts of blood	929.77
" " serum	900.50

1000 parts of blood contained—

Water	829.77
Blood-corpuscles and fibrin	78.55
Solid constituents of serum	91.68

1000 parts of blood contained—

Moist blood-corpuscles	314.20	Water	235.65
		Solid constituents	78.55
Liquor sanguinis	685.80	Water	594.12
		Solid constituents	91.68

The colon was occupied by a considerable amount of vegetable matters satu-

rated with juices, and incompletely digested. Hence it appears that the Gopher has the power of retaining, in its intestines, vegetable food for months, without either digesting it or allowing it to ferment or putrefy. When this vegetable food is removed from the intestinal canal, it putrefies in the course of one or two days.

By comparing this analysis with that of the blood of the Gopher in a normal condition, and the blood of the Alligator, *Emys terrapin*, and *Emys serrata* during starvation, we see that the blood of the Gopher is slowly affected by starvation and thirst. This endurance of abstinence from food and drink is a consequence of the following conditions:—

1. The large supply of vegetable food in the great intestine, which continually replaces the wastes of the blood, organs, and tissues.

2. The body is covered, in all parts exposed, with horny excrescences, which prevent the escape of moisture. These are especial provisions of nature, adapting this animal to a barren and dry country.

Series V.—Effects of Thirst and Starvation upon the Solids and Fluids of a Warm-blooded Animal.

36. Blood of a Cur-Dog in a normal condition.

For a week previous to this analysis, the dog was supplied with more mutton than he could devour. Upon this diet he became very fat and fleshy. On the day previous to the analysis, all food was discontinued.

Weight of dog, 6½ o'clock P. M., August 7, 23¾ lbs.

The blood for analysis was abstracted at 9 o'clock P. M. It coagulated in a few moments after it left the body.

The serum was clear.

Specific gravity of the blood	1045.5
" " serum	1030.5
Solid constituents in 1000 parts of blood	193.48
" " " serum	119.67
" in serum of 1000 parts of blood	109.64
Water in 1000 parts of blood	806.52
" " serum	880.33

1000 parts of blood contained—

Water	806.52
Blood-corpuscles (dried organic residue)	78.04
Albumen, fatty and extractive matter	106.18
Fibrin	3.15
Fixed saline constituents	6.11

1000 parts of blood contained—

Moist blood-corpuscles	322.76	Water	242.07
		Solid constituents	80.69
Liquor sanguinis	677.24	Water	564.45
		Solid constituents	112.79

37. Four o'clock P. M., August 11, fourth day of starvation.

The blood coagulated in a few moments after it was drawn.

Specific gravity of blood	1054.5
" serum	1036.8
Solid constituents in 1000 parts of blood	229.10
" " " serum	134.45
" in serum of 1000 parts of blood	117.18
Water in 1000 parts of blood	770.90
" " serum	865.55

1000 parts of blood contained—

Water	770.90
Blood-corpuscles (dried organic constituents)	102.55
Albumen, fatty and extractive matter	112.53
Fibrin	4.92
Fixed saline constituents	9.10

1000 parts of blood contained—

Moist blood-corpuscles	428.00	Water	321.00
		Solid constituents	107.00
Liquor sanguinis	572.00	Water	449.90
		Solid constituents	122.10

38. Nine o'clock P. M., August 13, sixth day of starvation and thirst.

The blood from the vein was black, flowed with difficulty, and resembled tar. It coagulated immediately after it left the bloodvessels into a firm clot. The blood flowed so slowly, and in such a small stream, that it was difficult to obtain a sufficient quantity for analysis. It had been consumed in supplying the waste of the system.

The dog, during the greater portion of the day, and while the blood was abstracted, lay in a comatose condition. It was completely exhausted, and showed, in its skeleton-like form, the ravages of hunger and thirst. By an unfortunate accident, my last specific gravity bottle was broken, and consequently the specific gravity of its blood and serum was not taken.

The serum was in small amount, relatively to the size of the clot, and was colored red by the hæmatin of the blood.

Many of the blood-corpuscles appear to have undergone partial decomposition. A similar condition of the blood and serum was observed previously in a large female *Emys serrata* during starvation.

Solid constituents in 1000 parts of blood	233.84
" " " serum	144.87
" in serum of 1000 parts of blood	129.80
Water in 1000 parts of blood	766.16
" " serum	855.13

1000 parts of blood contained—

Water		766.16
Blood-corpuscles (dried organic constituents)		96.76
Albumen, fatty and extractive matter		126.32
Fibrin		2.92
Fixed saline constituents of blood corpuscles	4.36	7.84
" " serum	3.48	

1000 parts of blood contained—

Moist blood-corpuscles	402.64	Water	301.98
		Solid constituents	100.66
Liquor sanguinis	597.36	Water	464.64
		Solid constituents	132.72

The dog died at eight o'clock A. M., August 14.

Weight when the experiment was commenced	$23\frac{3}{4}$ lbs.	= 161,326 grains.
Weight after death	$16\frac{1}{8}$ "	= 112,055 "

In 158 hours (6 days and 14 hours) this dog had lost 49,271 grains; one-third to one-fourth of its original weight. Loss of weight during twenty-four hours, 7,476 grains. Loss of weight during one hour $311\frac{5}{10}$ grains $= \frac{1}{517}$ of the weight of its whole body before starvation. During 158 hours of starvation, each pound Avoirdupois (7,000 grains) lost 2,078 grains.

The liver was tested the next morning for grape sugar, but the tests of Trommer and Moore failed to indicate its presence.

The substance of this organ, under the microscope, contained innumerable oil-globules of various sizes. All the fat throughout the body appeared to have been completely consumed. The only source of this fat was the nitrogenized elements of the blood and tissues, which were acted upon by the cells of the liver.

It is stated by physiologists that, after prolonged starvation, the amount of urea formed in the system is increased. The reason of this is obvious. The fat stored up in various parts of the body is first consumed to sustain animal temperature. As long as it supplies the demands of nature, urea, a product of the metamorphoses of the nitrogenized elements of the blood and tissues, is found in normal amount. When, however, the fat is consumed, the nitrogenized elements of the blood and tissues are attacked. The carbon unites, ultimately, with oxygen, forming carbonic acid, whilst the nitrogen is conjoined with oxygen and carbon, and is thrown off as urea. We have, then, in addition to the amount of urea normally formed, that which results from the combustion of the nitrogenized compounds.

The dense and dry condition of the muscular system of the dog, showed that the juices of the muscles must have passed into the blood. This results as a necessary consequence of the physical law of endosmosis.

During starvation and thirst, the blood becomes denser than the surrounding fluids, owing to the evaporation of water which goes on continually in the lungs. The less dense juices of the body necessarily flow into the circulatory system. The object of all endosmotic action is the restoration of an equilibrium, and the rapidity of that action will be determined, in great measure, by the differences of the densities of the exterior and interior solutions.

It is probable that the death of this dog occurred sooner than should have been anticipated, on account of the heat. During the middle of the day, the thermometer generally stood as high as 94°. This heated atmosphere promoted evaporation of the watery elements of the blood and tissues, both from the surface of the body and lungs.

These experiments complete our investigations upon the effects of thirst and starvation upon the blood of different animals. We will now arrange the results in tables, and study them collectively.

I. *Tables showing the Changes in the Relative Amounts of the Organic and Inorganic Constituents of the Blood of Warm and Cold-blooded Animals, during different periods of Starvation and Thirst. The numbers represent the amounts existing in 1000 parts of blood. The changes, therefore, are relative and not absolute.*

(*a.*) SPECIFIC GRAVITIES, WATER, AND SOLID CONSTITUENTS OF BLOOD AND SERUM.

Name of animal.	Period of starvation and thirst.	Specific gravity of blood.	Specific gravity of serum.	Water in 1000 parts of blood.	Water in 1000 parts of serum.	Solid constituents in 1000 parts of blood.	Solid constituents in 1000 parts of serum.	Solid constituents in serum of 1000 parts of blood.
Female Alligator . .		1046.0		823.86	909.20	176.14	90.80	82.05
Male Alligator . .	17½ days	1056.0		803.43	909.20	196.57	90.80	80.24
1st female *Emys terrapin* .	12 hrs.	1035.3	1012.7	845.28	956.17	154.72	43.83	38.75
2d " " .	40 days			800.59	920.50	199.41	79.50	69.15
3d " " .	57 "			744.78	888.04	255.22	111.96	92.82
1st female *Emys serrata* .	3½ "	1026.5	1013.7	875.41	956.97	124.59	43.03	39.36
2d " " .	17 "	1040.5		821.89	935.49	178.11	64.51	56.68
3d " " .	24 "			793.72	911.33	206.28	88.67	77.49
4th " " .	26 "	1043.0		801.34	904.52	198.66	95.48	84.59
5th " " .	31 "			777.78		222.22		
6th " " .	38 "			773.38	845.00	226.62	155.00	141.86
7th male " .	49 "	148.7		800.94	891.10	199.06	108.90	97.88
1st male *Testudo polyphemus*		1030.0	1018.0	843.38	933.59	156.62	66.41	60.00
2d " "	30 days	1037.0	1017.0	854.77	938.84	147.23	61.16	55.55
3d " "	51 "			829.77	900.50	170.23	99.50	91.68
1st Cur-dog . . .		1045.5	1030.5	806.52	880.33	193.48	119.67	109.69
2d " . . .	96 hrs.	1054.5	1036.8	770.90	865.55	229.10	134.45	117.18
3d " . . .	158 "			766.16	855.13	233.84	144.87	129.80

(*b.*) CONSTITUENTS OF 1000 PARTS OF BLOOD.

Name of animal.	Period of starvation and thirst.	Water.	Blood-corpuscles (dried organic constituents).	Albumen, fatty and extractive matters.	Fibrin.	Fixed saline constituents.
Female Alligator . .		823.86	86.39	78.03	3.07	8.65
Male Alligator . .	17½ days	803.43	106.80	76.02	3.41	10.34
1st female *Emys terrapin*	12 hours	845.28	103.82	36.01	4.15	10.74
2d " "	40 days	800.59	118.56	64.85	5.26	10.74
3d " "	57 "	744.78	156.98	90.87	1.85	5.52
1st female *Emys serrata*	3½ "	875.41	80.67	37.66	1.04	5.22
2d " "	17 "	821.89	115.75	54.68	1.68	6.00
3d " "	24 "	793.72	122.26	74.49	1.68	7.85
4th " "	26 "	801.34	102.97	80.09	4.15	11.45
5th " "	31 "	777.78				12.56
6th " "	38 "	773.38	72.91	134.49	6.52	12.70
7th male "	49 "	800.94	92.29	93.38	4.34	9.05
1st male *Testudo polyphemus*		843.38	87.28	57.78	5.73	5.83
2d " "	30 "	852.77	84.76	53.17	2.99	6.13
3d " "	51 "	829.77	78.55			
1st Cur-dog . . .		806.52	78.04	106.18	3.15	6.11
2d " . . .	4 "	770.90	102.55	112.53	4.92	9.10
3d " . . .	158 hours	766.16	96.76	126.32	2.92	7.84

(*c.*) MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

Name of animal.	Period of starvation and thirst.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
		Moist blood-corpuscles in 1000 parts of blood.	Water in moist blood-corpuscles.	Solid constituents in moist blood-corpuscles.	Liquor sanguinis in 1000 parts of blood.	Water in liquor sanguinis.	Solid constituents in liquor sanguinis.
Female Alligator . .		364.08	273 06	91.02	635.92	550.80	85.12
Male Alligator . .	17½ days	451.68	338.76	112.92	548.32	464.67	83.65
1st female *Emys terrapin*	12 hours	447.28	335.46	111.82	552.72	509.82	42.90
2d " "	40 days	500.00	375.00	125.00	500.00	425.59	74.41
3d " "	57 "	642.20	481.65	160.55	357.80	263.13	94.67
1st female *Emys serrata*	3½ "	336.76	252.57	84.19	663.24	622.84	40.40
2d " "	17 "	478.00	358.25	119.75	522.00	463.64	58.36
3d " "	24 "	508.44	381.33	127.11	491.56	412.39	79.17
4th " "	26 "	439.68	329.76	109.92	560.32	471.58	88.74
6th " "	38 "	312.96	234.72	78.24	687.04	538.66	148.38
7th male "	49 "	387.36	290.52	96.84	612.64	510.42	102.22
1st male *Testudo polyphemus* (Gopher)		393.56	302.67	90.89	606.44	540.71	65.73
2d " "	30 "	355.76	267.07	88.69	644.24	585.70	58.54
3d " "	51 "	314.20	235.65	78.55	685.80	594.12	91.68
1st Cur-dog . . .		322.76	242.07	80.69	677.24	564.45	112.79
2d " . . .	4 "	428.00	321.00	107.00	572.00	449.90	122.10
3d " . . .	158 hours	402.64	301.98	100.66	597.36	464.64	132.72

II.—*Tables showing the Actual Amounts of Blood and its Constituents existing in Animals during different periods of Starvation and Thirst.*

(*e.*) WATER AND SOLID CONSTITUENTS OF BLOOD AND SERUM.

Name of animal.	Period of starvation and thirst.	Amount of blood obtained.	Water of blood.	Solid constituents of blood.	Solid constituents of serum.
		Grains.			
1st female *Emys terrapin* . .	12 hours	1000	845.28	154.72	38.75
2d " " . .	40 days	400	320.23	79.76	27.66
3d " " . .	57 "	200	148.96	51.04	18.56
1st female *Emys serrata* . . .	3½ "	2000	1750.82	249.18	78.72
2d " " . . .	17 "	800	657.51	142.48	45.26
3d " " . . .	24 "	500	396.86	103.14	38.74
4th " " . . .	26 "	450	360.60	89.40	38.06
6th " " . . .	38 "	200	154.68	49.32	28.37
7th male " . . .	49 "	500	400.47	99.53	48.94

(*f.*) CONSTITUENTS OF BLOOD.

Name of animal.	Period of starvation and thirst.	Amount of blood obtained.	Water.	Blood-corpuscles.	Albumen, fatty and extractive matter.	Fibrin.	Fixed saline constituents.
		Grains.					
1st female *Emys terrapin*	12 hours	1000	845.28	103.82	36.01	4.15	10.74
2d " "	40 days	400	320.23	47.43	25.95	2.11	4.29
3d " "	57 "	200	148.96	31.40	18.17	.37	1.10
1st female *Emys serrata*	3½ "	2000	1750.82	161.34	75.32	2.08	10.44
2d " "	17 "	800	657.51	92.60	43.75	1.34	4.80
3d " "	24 "	500	396.86	61.13	37.24	.84	3.92
4th " "	26 "	450	360.60	46.34	36.05	1.68	5.15
6th " "	38 "	200	154.68	14.58	26.90	1.30	2.54
7th male "	49 "	500	400.47	46.15	46.69	2.17	4.52

(*g.*) MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

Name of animal.	Period of starvation and thirst.	Amount of blood obtained.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
			Moist blood corpuscles.	Water of moist blood corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
		Grains.						
1st female *Emys terrapin*	12 hrs.	1000	447.28	335.46	111.82	552.72	509.82	42.90
2d " "	40 days	400	200.00	150.00	50.00	200.00	170.23	29.77
3d " "	57 "	200	128.44	96.33	32.11	71.56	52.63	18.93
1st female *Emys serrata*	3½ "	2000	673.52	505.14	168.38	1326.48	1245.68	80.80
2d " "	17 "	800	383.80	387.85	95.95	416.20	369.60	46.60
3d " "	24 "	500	254.22	190.67	63.55	245.78	206.20	39.58
4th " "	26 "	450	197.92	148.44	49.48	252.08	212.16	39.92
6th " "	38 "	200	62.60	46.95	15.65	137.40	107.73	29.67
7th male "	49 "	500	193.67	145.26	48.42	306.32	255.21	51.11

The following tables have been constructed by calculations based upon careful comparisons of the blood of starved animals with the blood of those in a normal condition. They are, therefore, not absolutely correct, but are the nearest approximation to the truth that can at present be obtained.

III.—*Tables showing the Losses of Blood and its Constituents by Animals during different periods of Starvation and Thirst.*

(*m.*) WATER AND SOLID CONSTITUENTS OF BLOOD AND SERUM.

Name of animal.	Period of starvation and thirst.	Amount of blood consumed.	Water of blood.	Solid constituents of blood.	Solid constituents of serum.
		Grains.			
2d female *Emys terrapin* . .	40 days	600	525.05	74.95	11.09
3d " " . . .	57 "	800	696.32	103.68	20.19
2d female *Emys serrata* . . .	17 "	700	655.60	44.40	13.78
3d " " . . .	24 "	1500	1353.96	146.04	39.98
4th " " . . .	26 "	1550	1390.22	159.78	40.66
6th " " . . .	38 "	1800	1596.14	204.86	62.69
7th male " . . .	49 "	1000	912.64	87.36	10.10

(*n.*) CONSTITUENTS OF BLOOD CONSUMED.

Name of animal.	Period of starvation and thirst.	Amount of blood consumed.	Blood-corpuscles consumed.	Albumen, fatty and extractive matter.	Fibrin.	Fixed saline constituents.	Water of blood consumed.
		Grains.					
2d *Emys terrapin*	40 days	600	56.39	10.07	2.04	6.45	525.05
3d "	57 "	800	72.42	17.84	3.78	9.63	696.32
2d female *Emys serrata*	17 "	700	28.41	12.74	0.22	3.03	655.60
3d " "	24 "	1500	100.21	38.08	1.24	6.52	1353.96
4th " "	26 "	1550	115.00	39.27	0.22	5.29	1390.22
6th " "	38 "	1800	146.76	48.42	0.78	7.90	1596.14
7th male "	49 "	1000	74.85	9.80	.61	3.31	912.64

(*o*.) MOIST BLOOD-CORPUSCLES AND LIQUOR SANGUINIS.

Name of animal.	Period of starvation and thirst.	Amount of blood consumed.	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
			Moist blood-corpuscles.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
		Grains.						
2d female *Emys terrapin*	40 days	600	247.28	185.46	61.82	352.72	339.59	13.13
3d " "	57 "	800	318.84	239.13	79.71	481.16	457.19	23.97
2d female *Emys serrata*	17 "	700	121.60	91.20	30.40	578.40	564.40	14.00
3d " "	24 "	1500	419.28	314.46	104.82	1080.72	1039.50	41.22
4th " "	26 "	1550	475.60	356.70	118.90	1074.40	1033.52	40.80
6th " "	38 "	1800	561.56	421.17	140.39	1238.44	1174.97	63.49
7th male "	49 "	1000	309.04	231.78	77.26	690.96	680.86	10.10

A careful review of the results of these analyses and experiments leads to the following conclusions:—

1. In every instance, during abstinence from food and drink, the water of the blood diminished more rapidly than the solid constituents.

The evaporation from the surface of the body and lungs, and the supply of a solvent for the excretions of the kidneys, were more rapid than the consumption of the solid organic, and inorganic constituents of the blood for the regeneration and maintenance of the tissues and organs.

2. The rapidity of this consumption of the watery element, and consequent concentration of the blood depends upon the vital and physical constitution of the animal, and is most rapid amongst warm-blooded ones.

Amongst cold-blooded animals it is slowest in the gopher. The physical constitution of the epidermis of this animal prevents evaporation from its surface. Its tissues, also, are more compact than those of other Chelonians.

The character of the food of this animal, and the structure of its alimentary canal, are such, that it is able to withstand the effects of hunger without any physical or chemical change in the amount and constitution of its blood, or diminution of its powers, much longer than the Chelonians which inhabit the water.

3. During thirst and starvation, the rapidity of the consumption of the constituents of the blood, organs, and tissues, is in proportion to the temperature, intelligence, vital force, and the amount of muscular and nervous force expended by the animals.

4. The blood-corpuscles waste during starvation, as well as the other constituents of the blood, thus proving that they have important offices to fulfil in the support of the tissues and organs of the living animals, and the maintenance of the vital, nervous, physical, and chemical phenomena.

5. The fibrin decreases during starvation and thirst.

Had we considered the amount of fibrin only in 1000 parts of blood, we would have fallen into an error committed by several observers. The increment of the fibrin in 1000 parts was only apparent, and corresponded in a great measure to the concentration of the blood by the rapid evaporation of its water from the surface of the body and lungs.

6. During long-continued starvation and thirst, the stomach and intestines of cold-blooded animals do not become inflamed and ulcerated, as is almost universally the case with warm-blooded animals.

7. The fat of the body wastes more rapidly than any of the tissues. The manner in which it re-enters the circulation is unknown.

The following tables will serve to elucidate phenomena which have been but imperfectly studied by naturalists and physiologists.

Table of the Temperatures of Warm and Cold-Blooded Animals.

	Temperature of Atmosphere.	Temperature of box or medium in which the animal was kept.	Temperature of region of	Temperature of region of
Micropogon undulatus (Croker Fish)		Water, 84°		Viscera, 84°
Heterodon platyrhinos (Hognose Viper)	75½°	Box, 73½°		Heart, 73°
Heterodon niger (Black Viper)	80½°		Tail, 74°	" 76°
Psammophis flagelliformis (Coachwhip Snake) . .	72°		" 73½°	" 74°
Alligator Mississippiensis (Alligator, starved 17 days . .	69°		Surface of body, 65°	" 69°
Chelonura serpentina (Snapping Turtle)	90°	" 85°	Muscles of thigh, 81°	" and Liver, 82°
Chelonia caretta (Loggerhead Turtle)	90°	Water, 81½°		" " 81°
Emys terrapin (Salt-water Terrapin)	78°	Box, 78°	" " 80°	" " 80¼°
Emys serrata (Yellow-bellied Terrapin) deprived of food and drink 3½ days . .	86½°	" 74°		" " 73½°
Emys serrata, deprived of food and drink 17 days . .	74½°	" 76°		" " 77°
Emys serrata, deprived of food and drink 21 days . .	86°	" 84°		" " 75½°
Emys serrata, deprived of food and drink 49 days . .	85°	" 81°	" " 80°	" " 80½°
Emys reticulata . . .	86°	" 80°		" " 80°
Testudo polyphemus (Gopher)	82°		" " 80°	" " 80½°
Corvus ossifragus (Fish Crow)	80½°		" " 104°	" " 108°
Ectopistes Carolinensis (Turtle Dove)	66°		Intestine, 106°	Pec. maj. muscle, 106½°
Syrnium nebulosum (Barred Owl)	76°			" " 102°
Ardea nycticorax (Night Heron)	78°½			" " 104°
Carduelis tristis (May Bird) .	82¾°			" " 105°
May Bird	82¾°			" " 106°
May Bird, which had lost much blood from a bad wound .	82¾°			" " 98°
May Bird, which had lost much blood from a wound . .	82¾°			" " 100¼°
May Bird, which had lost much blood	82¾°			" " 101°
Mammalia generally . .				Heart, 100°

Table showing the Relation between the Temperature and the Chemical Changes of the Molecules of the Solids and Fluids of Warm and Cold-Blooded Animals.

Name of Animal.	Temperature of the atmosphere and box in which the animal was kept.	Temperature of the region of	Temperature of the region of	Loss of weight each hour.	Loss of weight each hour expressed in a fraction of the original weight of the animal.	Amount of urine excreted hourly.	Amount of urine excreted hourly, expressed in a fraction of the original weight of the animal.	Amount of solid constituents in the urine excreted hourly.
	Fahr.	Fahr.	Fahr.	Grains.		Grains.		Grains.
Emys terrapin .	78°	Muscles of thigh, 80°	Heart and liver, $80\frac{1}{4}$°	5.18	$\frac{1}{3635}$	.032	$\frac{1}{446406}$	.00114
Emys serrata . .	74°		" $73\frac{1}{2}$°	6. 3	$\frac{1}{3313}$	1.315	$\frac{1}{15865}$	.0034
Emys serrata . .	76°		" 77°	10. 5	$\frac{1}{2870}$	0.357	$\frac{1}{846500}$	.00166
Emys serrata . .	84°		" $75\frac{1}{2}$°	10.29	$\frac{1}{3754}$	1.09	$\frac{1}{34357}$	.00437
Emys serrata . .	81°	" 80°	" $80\frac{1}{2}$°	3.14	$\frac{1}{5667}$	.0277	$\frac{1}{642130}$	.0012
Testudo polyphemus	82°	" 80°	" $80\frac{1}{2}$°	2.41	$\frac{1}{7621}$			
Cur-dog . . .	86°		" 100°	311.84	$\frac{1}{517}$			

These tables show that, although the union of the oxygen of the atmosphere with the elements of the solids and fluids of cold-blooded animals is so slow that their temperature changes with that of the surrounding medium, still they generate within themselves a certain amount of heat. This is proved by the fact, that, the interior of their bodies in the region of the heart and liver generally has a temperature a fraction of a degree higher than that of the parts nearer the surface.

The fact that the temperature of their bodies is often several degrees below that of the surrounding medium is readily explained by a reference to our investigations upon the effects of thirst and starvation upon the solids and fluids. The loss of weight is due, in a greater degree, to the evaporation of the water of the solids and fluids than to the metamorphosis and final elimination of the organic elements in the maintenance of animal temperature. The amount of solid matters consumed in the maintenance of the temperature of cold-blooded animals is not always sufficient to supply the heat abstracted by evaporation.

Losses in the Weights of Animals during different periods of Thirst and Starvation.

Name of animal.	Period of starvation and thirst.	Weight before starvation.	Weight after starvation.	Loss of blood during starvation.	Loss of weight during starvation.	Loss of weight compared to weight of body.	Loss of weight each hour.	Loss of weight per hour, compared to weight of body.
		Grains.	Grains.	Grains.	Grains.		Grains.	
Female *Emys terrapin*	38 days	14,285	11,400	600	2,885	$\frac{1}{5}$	3.317	$\frac{1}{4366}$
" "	56 "	12,280	9,255	800	3,025	$\frac{1}{4}$	2.25	$\frac{1}{5458}$
Female *Emys serrata*	12 hours	33,417	33,258		159	$\frac{1}{200}$	13.25	$\frac{1}{2728}$
" "	14 days	20,873	18,756	700	2,117	$\frac{1}{10}$	6.3	$\frac{1}{3313}$
" "	20 "	34,155	28,675	1500	5,480	$\frac{1}{6}$	11.41	$\frac{1}{2994}$
" "	20 "	41,086	34,960	1550	6,126	$\frac{1}{7}$	12.76	$\frac{1}{3298}$
" "	39 "	38,590	30,142	1800	8,398	$\frac{1}{4}$—$\frac{1}{5}$	10.29	$\frac{1}{3754}$
Male *Emys serrata*	45 "	17,797	14,400	1000	3,397	$\frac{1}{5}$	3.14	$\frac{1}{5667}$
6 *Emys serrata*	27 "	104,698	85,573		19,125	$\frac{1}{5}$—$\frac{1}{6}$	27.97	$\frac{1}{3743}$
Testudo polyphemus (Gopher)	25 "	18,368	16,922		1,446	$\frac{1}{13}$	2.41	$\frac{1}{7621}$
4 *Testudo polyphemus* (Gophers)	37 "	98,280	86,696		11,582	$\frac{1}{9}$	13.04	$\frac{1}{7536}$
Cur-dog	6 d'ys, 14 hours	161,326	112,055		49,271	$\frac{1}{3}$	311.84	$\frac{1}{517}$

A careful consideration of these tables, in connection with previous researches, will tend to support the following conclusions:—

1. The intellect, temperature, nervous and muscular forces, and organic development of animals, are in proportion to the rapidity of the changes of the elements.

In warm-blooded animals, which are endowed with intellect of a high order, and possess great nervous and muscular force, and correspondingly developed organs, the changes in their elements are incessant. When starved, they lose weight rapidly.

In cold-blooded animals, the temperature of which is often below that of the surrounding medium, and whose nervous system and intellect are feebly developed, the changes in their elements are correspondingly slow.

The Cur-dog lost, in six days and fourteen hours, one-third of its original weight, whilst the Chelonians lived from thirty to sixty days without losing more than from one-fourth to one-thirteenth of their original weight. The loss in the former was from six to fifteen times more rapid than in the latter.

2. The loss of weight at the time of death was very nearly equal in warm and cold-blooded animals. The maintenance of the short, vigorous life of the former, required as large a supply of organic and inorganic materials as the prolonged and sluggish existence of the latter. What the warm-blooded animal gained in intensity and power, it lost in duration.

3. The length of life of an animal during starvation and thirst, is proportional to the rapidity of the changes of its elements, and, as a necessary consequence, stands in direct relation to its temperature, intellect, and organic development.

The Cur-dog wasted more rapidly, lived more energetically, and died in a correspondingly shorter time, than the cold-blooded Chelonians.

Amongst cold-blooded animals, the Terrapins which were most active in their movements, and whose nervous system was the most excited, lived during a time corresponding with their increased nervous and muscular exertions.

The female Terrapins, whose ovaries and oviducts were filled with hard and soft eggs, lost from $\frac{1}{2728}$th to $\frac{1}{3313}$th of their weight hourly, and died in the course of twenty-five or thirty-five days; while the females which had deposited their eggs, and the males, which were free from these anxieties, wasted only one-half as much per hour—$\frac{1}{4366}$th to $\frac{1}{5667}$th of their whole weight—and lived twice the length of time—from fifty to seventy days.

We may infer from these facts, as far as they extend, that the acts of life are carried on upon the same general plan, no matter what be the physical or vital constitution of an animal.

4. In cold-blooded animals, the organs, tissues, and apparatus are far more independent of the blood than in warm-blooded ones.

This fact will explain the phenomena of the prolonged contraction of the heart and muscles, and the action of the nervous system, and the continuance of life, for a great length of time after the almost complete removal of the blood. These functions are attended with so little waste, and consequent demand for a fresh supply of nutriment, that a very small amount of the circulatory fluid will suffice to keep them in action for a great length of time.

In warm-blooded animals, on the other hand, the maintenance of the nervous

and vital forces, and of a definite temperature, and the exercise of the intellect, involve more decided and constant changes in their elements.

The circulatory apparatus filled with blood is the great laboratory in which these physical and chemical changes of the elements are carried on and the results distributed to every living molecule of matter. According, then, to the perfection of an animal, and the rapidity of these changes, will be the dependence of the organs and apparatus upon the circulatory fluid. It follows as a necessary consequence that the deprivation of this fluid will prove fatal in a length of time inversely proportional to the development and perfection of an animal.

The question now presents itself: Why is the life of cold-blooded animals so sluggish, and all the physical and chemical changes of their elements so tardy, and their temperature and intellect so low? Can Nature be said to be uniform in her operations when all the phenomena of life are so dissimilar in these two classes of animals?

A consideration of the important differences existing between the structure and functions of their respiratory and circulatory systems may serve to settle definitely this question, as will be seen in the course of this chapter.

The principal or only heart in many fishes, has but one auricle and one ventricle, and is traversed by venous blood alone, and corresponds with the right heart of the higher vertebrata.

Although the circulatory apparatus is more highly developed in the reptiles, still a mixture of venous and arterial blood always takes place in the ventricle.

As our experiments have been confined almost exclusively to the higher orders of cold-blooded animals, we shall consider briefly the circulatory and respiratory systems of the Ophidia, Sauria, and Chelonia.

The ventricle of the heart in these higher orders is generally divided by an imperfect septum, which, in the heart of the alligator, is very strong and almost complete. Just at the outlet of the ventricle, however, we find a communication established between the two, and thus the venous and arterial blood are mixed together, and the similarity to the heart of the rest of the reptiles, and the fœtus of birds and mammals, is preserved. The venous blood from all parts of the body is returned to the right auricle of the heart through the venæ cavæ, the terminations of which are guarded by strong valves. The left auricle is appropriated exclusively to the lungs, from which it receives the aerated blood through the pulmonary veins. From the single ventricle two sets of vessels are sent off, the pulmonary and the aortic. The pulmonary artery divides into two branches, one for each lung. The aorta, immediately after its origin, divides into two trunks, which, winding backwards, join and form a large vessel, the branches of which distribute the blood to all parts of the system. The contraction of the right auricle forces the venous blood into the ventricle, whilst the contraction of the left auricle transmits the aerated blood from the lungs into the same common cavity. The contraction of the ventricle distributes a portion of the mixed blood into the lungs through the pulmonary artery, and the remainder to all parts of the body through the aorta and its branches.

From this arrangement it is evident, that not only is partially aerated blood diffused throughout the system, but, also, that a moiety only of the whole amount of blood is sent to the lungs and exposed to the action of the atmosphere at each contraction of the ventricle of the heart.

From the consideration of the heart and circulatory apparatus of the Chelonia and Sauria, we pass very naturally to that of warm-blooded animals.

The circulatory apparatus differs in no essential respect in the two great classes of warm-blooded animals, birds and mammals.

In these higher animals we have a double heart, and two distinct and complete circulations of the blood. Each portion of blood which has passed through the capillaries of the system and become vitiated, is aerated in the lungs before its distribution over the body. This is one of the most important of all distinctions between warm and cold-blooded animals.

The right heart is devoted to the circulation of venous blood, and the left heart to the circulation of oxygenated or aerated blood.

The auricle and ventricle of one heart have no communication with the auricle and ventricle of the other except through the bloodvessels and capillaries. The vessels of each heart are distinct, and perform distinct offices.

The right auricle receives the venous blood from all parts of the system and transmits it to the right ventricle. The contraction of the right ventricle distributes the venous blood to the lungs. The oxygenated or arterial blood is conveyed from the lungs to the left auricle, and thence to the left ventricle, and the contractions of this distributes it throughout all parts of the system.

As the circulatory apparatus is developed, the influence and importance of the nervous system are increased, and corresponding arrangements established for its perfect preservation.

Another consideration to be taken into account is the relative size of the heart and the rapidity of its action in different animals.

I obtained the following results by carefully weighing the entire body of an animal, and then ascertaining the weight of its heart upon a delicate balance capable of turning to the $\frac{1}{1000}$th part of a grain.

Comparative Weights of the Hearts of Fishes.

	Proportion to weight of entire animal.
Weight of the heart of female *Trygon sabina* (Stingray) . . .	$\frac{1}{1012}$
" " fœtus of *Trygon sabina* (Stingray) . . .	$\frac{1}{1070}$
" " *Zygæna malleus* (Hammerhead Shark) . . .	$\frac{1}{1156}$
" " *Zygæna malleus* (Hammerhead Shark) . . .	$\frac{1}{899}$
" " female *Lepisosteus osseous* (Garfish) . . .	$\frac{1}{965}$

Comparative Weights of the Hearts of Reptiles.

	Proportion to weight of entire animal.
Weight of the heart of *Rana catesbæana* (Bullfrog)	$\frac{1}{576}$
" " *Heterodon niger* (Black Viper)	$\frac{1}{496}$
" " *Coluber constrictor* (Black Snake)	$\frac{1}{425}$
" " *Coluber guttatus* (Corn Snake)	$\frac{1}{400}$
" " *Psammophis flagelliformis* (Coachwhip Snake)	$\frac{1}{354}$
" " *Crotalus durissus* (Rattlesnake)	$\frac{1}{441}$
" " *Chelonura serpentina* (Snapping Turtle)	$\frac{1}{405}$
" " *Chelonia caretta* (Loggerhead Turtle)	$\frac{1}{480}$
" " *Emys reticulata* (Chicken Terrapin)	$\frac{1}{420}$
" " *Emys serrata* (Yellow-bellied Terrapin)	$\frac{1}{592}$
" " *Emys serrata* (Yellow-bellied Terrapin)	$\frac{1}{577}$
" " *Emys serrata* (Yellow-bellied Terrapin)	$\frac{1}{543}$
" " male *Testudo polyphemus* (Gopher)	$\frac{1}{455}$
" " male *Testudo polyphemus* (Gopher)	$\frac{1}{470}$
" " female *Alligator Mississippiensis* (Alligator)	$\frac{1}{398}$

Comparative Weights of the Hearts of Birds.

	Proportion to weight of entire animal.
Weight of the heart of *Meleagris gallopavo* (Wild Turkey)	$\frac{1}{279}$
" " *Meleagris gallopavo* (Wild Turkey)	$\frac{1}{275}$
" " *Syrnium nebulosum* (Barred Owl)	$\frac{1}{220}$
" " *Cathartes atratus* (Turkey-buzzard)	$\frac{1}{113}$
" " *Tantalus loculator* (Wood Ibis)	$\frac{1}{108}$
" " *Tantalus loculator* (Wood Ibis)	$\frac{1}{100}$

Comparative Weights of the Hearts of Mammals.

	Proportion to weight of entire animal.
Weight of the heart of Common Sheep	$\frac{1}{256}$
" " *Sciurus Carolinensis* (Gray Squirrel)	$\frac{1}{261}$
" " *Didelphis Virginianus* (Opossum)	$\frac{1}{280}$
" " Common Cat	$\frac{1}{275}$
" " *Procyon lotor* (Raccoon)	$\frac{1}{164}$
" " *Procyon lotor* (Raccoon)	$\frac{1}{146}$
" " young *Procyon lotor* (Raccoon)	$\frac{1}{142}$
" " Pointer Dog	$\frac{1}{128}$

By comparing these tables, we see that the heart is proportionally smallest in Fishes and largest in Birds.

As the organs and apparatus of the animal economy are developed and perfected, the circulation of the nutritive materials becomes more vigorous.

As the temperature, intelligence, and activity of animals, with their corresponding physical and chemical metamorphoses of the elements of organic structure increase, there is a correspondingly rapid supply of those materials by which the wastes may be repaired, and from which the various secretions and excretions may be elaborated and separated.

The next consideration is the rapidity of the circulation in different animals.

The action of the heart may be taken as a general index of this. The following table has been drawn up from the researches of Dumas, Prevost, Müller, and Simon.

Rapidity of Circulation in Different Animals.

	Number of beats per minute.
In the *Amphioxus*	1
" Carp	20
" Fishes generally	20—24
" Green Toad	77
" Frogs generally	about 60
" Pigeon	136
" Common Hen	140
" Duck	110
" Raven	110
" Heron	200
" Birds generally	100—200
" Ox	38
" Horse	56
" Sheep	75
" Goat	84
" Hare	120
" Guinea-Pig	140
" Dog	90—95
" Cat	100—110
" Ape (*Simia Callitriche*)	90
" Human embryo	150
" " just after birth	130—140
" Human being during first year	130—115
" " during second year	115—100
" " during third year	100—90
" " about seventh year	90—85
" " about fourteenth year	85—80
" " in the middle period of life	75—70
" " in old age	65—50
" Mammals generally	38—140

This table shows that the rapidity of the circulation corresponds with the structure, habits, age, and development of animals.

If the vital forces are of a low grade, either from original conformation or the depressing influences of old age, the circulation is correspondingly sluggish and feeble.

As the fluids and solids of animals become more highly elaborated and developed, the action of the heart and circulation of the blood become more rapid and vigorous.

The next consideration is that of the structure of the respiratory system in the different orders of animals.

One of the essential conditions of the life of all organized beings, whether vegetable or animal, is a supply of oxygen. The modes in which oxygen is brought in contact with the fluids and solids of organized structures, vary with the development and peculiar manner of life of the different classes of animals.

In the lowest classes of the Invertebrata, in which the digested matters pass directly from the stomach into the different structures of the body, and become integral parts of the animal, we find no special circulatory system, and respiration

is carried on by the whole surface of the body which is bathed by the water. In animals still more highly developed, we find canals carrying water into all parts of the system. In many individuals, bloodvessels accompany these canals, and ramify around their walls. An incessant motion through this aquiferous respiratory system is maintained by cilia lining their interior. These canals open upon the exterior of the body and into the visceral cavity. In many animals of this class, the digestive cavity, which is bathed continually by fresh portions of water, performs the function of respiration.

In the higher orders of the Invertebrata, the respiratory system is confined to a definite portion of the exterior or internal membrane, which is developed within a small space into a great extent of surface, so as to render the contact with the air or water as extensive as possible without any loss of room or power.

According as the fluids are elaborated, and the solids correspondingly developed, the respiratory system becomes more condensed and perfected.

In the *Amphioxus*, or the pulmonary apparatus corresponds with the degraded type of the cerebro-spinal system and all the organs, and, like that of many invertebrate animals, is lodged in the same cavity with the liver, generative apparatus, kidneys, and the greater portion of the alimentary canal. In the Invertebrate animals and the *Amphioxus* amongst the Vertebrate, the circulation of the water through the branchiæ is maintained principally by ciliary action.

In Fishes, however, of higher organization, whose blood is more highly elaborated and circulates with greater rapidity, mere filamentous tufts hanging to the side of the neck will not suffice for the aeration of the blood. It is necessary that large streams of water be constantly and forcibly propelled through the branchial apparatus, in order that the blood may be exposed as much as possible to the action of the air so scantily contained in the water. This is accomplished by the connection of the gills with the cavity of the mouth, the muscles of which send rapid currents of water through the branchial passages. The structure and position of the heart, also, is such that it propels all the venous blood through the branchiæ before its distribution to the body generally.

At first sight, the circulation and respiration of Fishes appear to be more perfect than that of Reptiles. This, however, is not the case. By a reference to the table of the comparative weights of the heart in different animals, it will be seen that the heart of Fishes is about $\frac{1}{1000}$th, whilst that of Reptiles is about $\frac{1}{450}$th of the weight of the entire body.

The heart of Reptiles is relatively more than twice as large as that of Fishes.

The table of the comparative rapidity of the heart's action in different animals, showed that the circulation of Fishes is much slower than that of Reptiles.

The aeration of the blood, also, is much slower and less perfect in Fishes, from the fact that the amount of air contained in the water is infinitely less than that of the atmosphere.

In several remarkable Fishes having strongly marked reptilian characters, as the Garfish (*Lepisosteus osseus*) and the common Mudfish (*Amia calva*) of our southern swamps and ricefields, we find both gills and a pulmonary organ. The lung of these Fishes has been considered by many physiologists and anatomists as analogous to

the swimming-bladder of other Fishes. This organ is absent in some individuals, and its presence or absence in those which possess it, appears to make no material difference; in some, it communicates externally, whilst in others again it is completely closed, and all its offices are unknown. It is, therefore, impossible, with our present knowledge, to decide whether the air-bladder of Fishes should be considered as a rudimentary lung.

The lung of the Garfish (*Lepisosteus osseus*) is a capacious sac, which opens by a short trachea high up in the throat, and, extending nearly the whole length of the abdominal cavity, terminates within a short distance of the anus. It lies between the posterior surface of the liver and the anterior surface of the kidneys. When removed from the abdominal cavity and inflated, its diameter is nearly equal to two-thirds of that of the fish. Its structure resembles that of the *Amphiuma means* and other doubtful Reptiles. The bloodvessels ramify upon the walls of this sac, the internal surface of which is increased by the development of numerous sacculi.

This increased development of the respiratory system is attended by corresponding improvements in the structure and functions of the solids.

The Gar is a destructive and active pirate, and consequently needs great muscular power to outstrip and capture the swift inhabitants of the watery element. It is a very difficult matter to hold a recently captured Gar, two or three feet in length, even with both hands, on account of the vigor and rapidity of its motion. In the possession of a lung, and in the general form and appearance of the viscera, this fish bears a strong resemblance to Reptiles. Fig. 11 represents the viscera of the fresh-water Garfish.

In the Congo Snake of our southern swamps and ricefields, and the Hellbender (*Menopoma Alleganiensis*), we find branchial arches without any development of the gills.

The lungs of the Congo Snake (*Amphiuma means*) communicate with the exterior through a short trachea, which opens by a slit in the pharynx, just opposite to the base of the cranium. The trachea passes down between the divisions of the *bulbus arteriosus*, and, a short distance below the position of the heart, divides into two short branches which open into the lungs. The lungs are long slender sacs, having the general structure of these organs in the Batrachia. The diameter of the lungs, even in their inflated condition, is very small, being about half an inch, whilst their length is very great in full-grown individuals, being about eighteen inches. Notwithstanding the absence of gills, the lungs are far smaller than the pulmonary organs of the Garfish (*Lepisosteus osseus*), which has also a large and well developed branchial apparatus. This may be due in part to the fact that its naked skin, as in Frogs and naked animals generally, whether vertebrate or invertebrate, performs the office of a lung.

The chief cause, however, of these discrepancies in the development of the respiratory organs of the two animals is to be found in their habits and vital endowments.

The Gar is active and powerful, whilst the *Amphiuma* is sluggish and degraded in habits and appearance. This is one of numerous instances which might be

adduced to show that the consumption of oxygen, and the corresponding waste of the tissues, corresponds exactly with the development, habits and temperature of animals. The viscera of this animal, reduced to one-half their diameter, are represented in Fig. 20.

The lungs of the several orders of reptiles are formed upon one type, being capacious sacs, whose walls are divided into sacculi, and supplied with bloodvessels according to the perfection of the organs and apparatus, and the habits of the animal.

From the internal surface membranous septa project inwards, dividing the interior of the organ into numerous polygonal cells, which are themselves subdivided into smaller compartments. The bloodvessels are distributed over the internal walls of the lungs and over the sides of the pulmonary cells.

In serpents one lung only is developed, and the pulmonary cells are most numerous in the superior portion, whilst the inferior part of the long cylindrical lung is a mere membranous sac with few or no bloodvessels ramifying upon its walls. (See Figure 21.)

We find the greatest number of the polygonal cells and the greatest distribution of the bloodvessels in the pulmonary organs of the Chelonia and Sauria, thus foreshadowing the condition of the lungs in birds and mammals.

In these orders the lungs are filled, more or less, by a coarse and fine network or areolar tissue, forming angular or rounded meshes, which rest partly upon the walls of the lungs, and enclose lesser meshes or air-cells. The bloodvessels ramify over the meshes as well as over the walls of the lungs. The sacculi thus formed communicate with each other, and can all be inflated from any one point.

The size of the lungs differs in the different orders according to their structure and habits. Amongst the Chelonians, we find the most capacious lung in the gopher (*Testudo Polyphemus*). These animals burrow deeply in the ground, and need large lungs as a reservoir of air. In aquatic serpents which remain under the water for a great length of time, the lungs are capable of holding a greater quantity than those of land serpents.

In mammals and birds the blood is abundant, and the circulation rapid, and the wastes and metamorphoses of the tissues correspondingly great, and the lungs are composed of an infinitude of minute cells containing air, and surrounded by a capillary network.

The respiratory system of birds is far more highly developed than that of reptiles, but not so concentrated as that of the mammals. In this class the lungs are no longer closed bags like those of reptiles, but are spongy masses of great vascularity communicating with numerous air-sacs and the cavities of the bones. The main trunks of the bronchial tubes pass through the lungs and open into the cavity of the thorax. The whole thoracico-abdominal cavity is divided by bands of serous membrane into numerous cells communicating with each other and the cavities of the hollow and spongy bones.

In many birds, especially those of powerful flight, the air is admitted into the interspaces between the muscles, and between the skin and muscular system. By this arrangement, which reminds us of the tracheal system of insects, the air pene-

trates almost every part of their bodies, bathes all their viscera, and fills the cavities of the hollow and spongy bones. It follows as a necessary consequence, that the actions between the oxygen of the atmosphere and the organic elements of their bodies should be rapid and incessant, and the temperature correspondingly high.

The minute structure of the lungs of birds resembles, in many respects, that of reptiles; the cells, however, are infinitely more numerous and minute, and the surface exposed to the action of the atmosphere correspondingly more extensive.

The entire mass of each lung is divided into innumerable lobules or lunglets, the walls of which are formed by a cartilaginous network derived from the bronchial tubes, and by the ramifications of the capillary vessels. From this arrangement, it is evident that the bloodvessels are suspended in air and exposed to its influence on every side. These cells or sacculi are never terminal cells, as in the mammalia, but open parietal cells, communicating freely with each other through the meshes of the capillary and cartilaginous network.

In the mammalia the abdominal cavity is completely separated from the thoracic cavity by the diaphragm, the great muscle of respiration. The lungs are closed bags situated in the cavity of the thorax, and are surrounded by a serous membrane, which, after lining the ribs and intercostal muscles and thoracic surface of the diaphragm, is reflected on the lungs from the point occupied by the pulmonic vessels.

They are composed of innumerable cells communicating with the terminal branches of the bronchial tubes, around which ramify a delicate and closely woven network of bloodvessels. Collectively, these cells present an immense surface, over which the blood circulates and is exposed to the action of the atmosphere. It has been calculated that the number of these air-cells grouped round the termination of each bronchial tube is about 18,000, and that the total number in the lung of the human being is not less than 600,000,000.

In the Amphibia and Batrachia, the lungs are filled by an action that resembles swallowing. In the Ophidia and Sauria, respiration is assisted by the ribs and abdominal muscles. In all cold-blooded animals the mechanism of respiration corresponds with the simple structure of their lungs and the sluggish metamorphoses of their tissue.

The mechanism of respiration in birds is more complete than that in reptiles, but not so perfect as that of the mammalia. From the elastic character of the cartilaginous and bony framework, surrounding the thoracico-abdominal cavity, the natural condition of the lungs is that of inflation. The air is expelled by the action of those muscles which bring the sternum nearer to the vertebral column. When these muscles cease to act, the extended sternum, attached to the elastic thorax, springs outwards, and the air rushes into the lungs to fill the vacuum thus formed.

In the mammalia, the inspiration and expiration of the air are effected by the alternate movements of the diaphragm and the walls of the thoracic cavity.

The relation which exists between the number of the respirations and the rapidity of the circulation of the blood will be seen in the following table drawn up from the researches of Dumas, Prevost, and Simon:—

	Number of the beats of the heart in one minute.	Number of respirations in one minute.
Horse	56	16
Hare	120	36
Goat	84	24
Cat	100	24
Dog	90	28
Guinea-pig	140	36
Ape (*Simia Callitriche*)	90	30
Man	72	18
Heron	200.	22
Raven	110	21
Duck	110	21
Common Hen	140	30
Pigeon	136	34

This table shows, that, as a general rule, the activity of the respiratory function corresponds with the rapidity of the circulation.

We are now prepared to understand the results of our experiments, and to show that the operations of nature are carried on upon the same great plan, however simple or complex the animal.

Cold-blooded animals are such, not from any peculiar chemical or physical endowments of the organic and inorganic molecules of their bodies, but from the peculiarity of the structure of their circulatory and respiratory systems.

The perfection of these two systems may be taken as the index of the rapidity of the physical and chemical changes of the molecules of their fluids and solids, and the facts we have presented lead to the conclusion, that the intelligence and activity of the vital actions are exactly proportional to the rapidity and amount of the physical and chemical changes of the organic and inorganic molecules.

Our investigations show that the heart of warm-blooded animals is from two to five times as heavy as that of reptiles, and is far more rapid and powerful in its actions, and, as a necessary consequence, that the blood circulates with much greater rapidity.

The respiratory system of reptiles is imperfectly developed, and its functions imperfectly performed. Only from one-sixth to one-ninth as much blood passes through their lungs, and is exposed to the action of the atmosphere, as circulates through the pulmonary organs of warm-blooded animals.

The blood-corpuscles, the active agents in the elaboration of many of the constituents of the blood, are much less numerous, and the whole amount of blood existing in their bodies is much less abundant in cold than in warm-blooded animals.

The nervous system, the great apparatus for the generation of the excitor-motive power of the animal economy, is imperfectly developed in cold-blooded animals.

From these data we are able to calculate, with almost absolute certainty, that the vital actions of cold-blooded animals should be from one-ninth to one-fifteenth as rapid as those of warm-blooded animals. Here we have a conclusive demonstration that modifications in vital phenomena are accomplished by peculiar modifications of the structure and arrangements of the various organs and apparatus, and by peculiar applications of the forces, and not by a suspension or alteration of the physical and chemical laws which govern all matter.

CHAPTER IV.

EFFECTS OF STARVATION AND THIRST, COMBINED WITH A CHANGE OF DIET, UPON THE FLUIDS AND SOLIDS OF CARNIVOROUS CHELONIANS.

SERIES I.—EXPERIMENTS UPON THE YELLOW-BELLIED TERRAPIN (*Emys serrata*).

39. Examination of a female *Emys serrata* which was starved four weeks, and then transferred to a tub of water, and abundantly supplied with Purslain (*Portulacca oleracea*).

It remained in the tub of water for forty-two days.

Weight, May 25	23.696	grains.
" June 21	19.472	"
Loss of weight in twenty-seven days—during which period it was deprived of all food and drink	4.224	"
Weight, August 2, after remaining forty-two days in the tub of water	25.333	"
Increase of weight in the forty-two days . . .	5.861	"
Gain above the original weight of May 25, . . .	1.637	"

The color of the blood was intermediate between arterial and venous.

The serum was of a light yellow color, resembling that of the Gopher (*Testudo polyphemus*) which subsists entirely upon vegetable food. The serum of the *Emys serrata* supplied with animal food, is always of a bright orange color. Here we see that the color had been changed from orange to light yellow by a change of diet.

In one portion of blood which was set aside, the fibrin did not coagulate until nearly all the blood-corpuscles had settled to the bottom, thus affording a transparent clot.

The portions of blood drawn last, coagulated much more rapidly than those drawn first.

The cellular tissue in all parts of the body of this Terrapin, was permeated by a limpid albuminous fluid, which coagulated when removed from the body. The coats of the peritoneum, the cavity of the abdomen and the pleura, contained large quantities of this fluid. The amount of this serous fluid, collected without any special care, was more than five fluidounces, equal to 2420 grains. Its specific gravity, 1005.9. As the blood flowed from the wound in the neck, this serous fluid passed into the bloodvessels, to supply the loss. This was shown by the change in the specific gravity of the serum. That obtained from the portions of blood first

drawn, gave a specific gravity of 1014, whilst that of a latter period, containing numerous blood corpuscles, gave a specific gravity of only 1012.9.

The arteries and veins had lost their elasticity, owing to the great pressure caused by the unusual amount of blood which they contained. After its removal they were unable to contract, and were found distended with air throughout all portions of the body. Even the heart contained air in its cavities. This phenomenon has never been witnessed in Terrapins fed upon animal food.

The tissues generally were relaxed, resembling those of a dropsical patient.

The shell had become much softer in its texture, the necessary amount of earthy salts not having been supplied by the Purslain (*Portulacca oleracea*).

The whole amount of blood obtained was much greater than that of Terrapins which were examined immediately after their capture, and which had been living in a normal manner.

Amount of blood obtained, about	2000	grains.
" " serous fluid from the tissues	2420	"
Specific gravity of the blood	1029.6	"
" " first portions of serum	1014	"
" " last " "	1012.9	"
" " serous fluid from tissues	1005.9	"

The bladder contained a large quantity of light yellow transparent urine, having a specific gravity not much higher than that of water.

Solid constituents in 1000 parts of blood	122.35
" " " serum	51.14
" " serum of 1000 parts of blood	47.30
Water in 1000 parts of blood	877.65
" " serum	948.86

1000 parts of blood contained—

Water	877.65
Blood-corpuscles (dried organic constituents)	70.53
Albumen, fatty and extractive matter	45.38
Fibrin	1.64
Fixed saline constituents	4.80

1000 parts of blood contained—

Moist blood-corpuscles	293.64	Water	220.23
		Solid constituents	73.41
Liquor sanguinis	706.36	Water	657.42
		Solid constituents	48.94

40. Examination of a female *Emys serrata*, which was starved and deprived of water twenty-eight days, and then transferred to a tub of fresh water and abundantly supplied with Purslain (*Portulacca oleracea*) eighty-eight days.

Weight, when it was first captured, May 25	20.372	grains.
" after starvation, June 21	15.797	"
Loss of weight during twenty-seven days of thirst and starvation	4.575	"

Weight, September 17, after removal from the tub	27.125 grains.
Gain in weight during eighty-eight days subsistence upon vegetable food	11.328 "

The serum was of a light-yellow color, and the clot was large.

The tissues of this terrapin did not present the dropsical appearance of those of the former terrapin.

The bladder was distended with light-yellow limpid urine, having a specific gravity only a few degrees above that of water.

The pleura and cellular tissue, along the side of the back, contained two fluid-ounces of a clear albuminous fluid, which coagulated when allowed to stand, and a well-defined soft clot was formed.

The intestines were much enlarged and distended, resembling those of Chelonians which live exclusively upon vegetable substances. The intestines of carnivorous terrapins in their normal condition are always contracted. This change was observed in the intestines of all those carnivorous terrapins which had been kept for a length of time upon vegetable food, and was, without doubt, due to the character of the food.

The stomach was filled with the buds and leaves of the Purslain, which gave an acid reaction.

The contents of the small intestines were neutral to test-paper.

The colon and rectum were filled with undigested vegetable matter, acid in its reaction.

The pancreas was diseased in this and many other carnivorous terrapins which had been fed entirely upon vegetable food. The diseased portion consisted of black and brown hard masses which could be squeezed out of the substance of the pancreas.

When subjected to the microscope, these masses were found to consist of numerous large yellow cells, with divisions and nuclei, resembling certain cancer cells; also oil-globules, and octohedral and columnar crystals. When the diseased portion was pressed upon the glass the crystals produced a grating noise. The cancer-like cells were found only in the diseased portion, whilst the crystals were found in other parts of the pancreas. We have never noticed this disease of the pancreas in terrapins in a normal condition, and the only cause which can be assigned for this degeneration of structure is the character of the food.

Solid constituents in 1000 parts of blood	115.84
" " " serum	50.00
" in serum of 1000 parts of blood	46.53
Water in 1000 parts of blood	884.16
" " serum	950.00

1000 parts of blood contained—

Water	884.16
Blood-corpuscles (dried organic constituents)	66.88
Solid constituents of serum	46.53
Fibrin	2.43

1000 parts of blood contained—

Moist blood-corpuscles	267.52	Water	200.64
		Solid constituents . . .	66.88
Liquor sanguinis	732.48	Water	683.52
		Solid constituents . . .	48.96

Other terrapins which had been treated in a similar manner were examined, and the results, in every instance, corresponded with those detailed above.

We shall next compare these analyses with those of the *Emys serrata* in its normal condition, and when deprived of food and drink. The following tables will give a condensed view of the changes in the amounts and chemical constitution of the blood of the *Emys terrapin* during thirst, starvation, and a change of diet.

	(a). *Specific Gravities and Water in* 1000 *parts of Blood and Serum.*				*Solid Constituents of Blood and Serum; Fibrin and Fixed Saline Constituents in* 1000 *parts of Blood.*			
	Specific gravity of blood.	Specific gravity of serum.	Water in 1000 parts of blood.	Water in 1000 parts of serum.	Solid constituents in 1000 parts of blood.	Solid constituents in serum of 1000 parts of blood.	Fibrin.	Fixed saline constituents.
(1). Female *Emys serrata* in a normal condition, having been captured 3½ days	1026.5	1013.7	875.41	956.97	124.59	39.36	1.04	5.22
(2). Female *Emys serrata*, which had been kept without food and drink 26 days.	1043.		801.34	904.52	198.66	84.59	4.15	11.45
(3). Female *Emys serrata*, which was kept without food and drink 28 days, and then transferred to a tub of water and abundantly supplied with vegetable food 42 days.	1029.6	1014.	877.65	948.86	122.35	47.30	1.64	4.80
(4). Female *Emys serrata*, which was kept without food and drink 28 days, and then transferred to a tub of water and abundantly supplied with vegetable food 88 days			884.16	950.00	115.84	46.53	2.43	

(b.) *Amount of Blood existing in these Terrapins.*

	Weight of Terrapin.	Amount of blood.
	Grains.	Grains.
(1). Female *Emys serrata* in a normal condition	33.258	2000
(2). Female *Emys serrata* deprived of food and drink 26 days .	28.675	450
(3). Female *Emys serrata* deprived of food and drink 28 days, and then transferred to a tub of water and abundantly supplied with vegetable food 42 days	25.333	2000

(c). *Moist Blood-Corpuscles and Liquor Sanguinis in* 1000 *parts of Blood.*

	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
	Moist blood-corpuscles.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
(1). Female *Emys serrata* in normal condition	336 76	252.57	84.19	663.24	622.84	40.40
(2). Female *Emys serrata* starved 26 days	439.64	329.76	109.92	560.32	471.58	88.74
(3). Female *Emys serrata* deprived of food and drink 28 days, and then transferred to a tub of water and supplied with vegetable food 42 days	293.64	220.23	73.41	706.36	657.42	48.94
(4). Female *Emys serrata* deprived of food and drink 26 days, and then transferred to a tub of water and supplied with vegetable food 88 days	267.52	200.64	66.88	732.48	683.52	48.96

SERIES II.—EXPERIMENTS UPON THE SALT-WATER TERRAPIN (*Emys terrapin*).

41. Examination of a female *Emys terrapin* which had been starved twenty-one days, then placed in fresh water, and abundantly supplied with Purslain.

It consumed large quantities of this vegetable, and was kept in the water for four weeks, Sept. 9.

The blood appeared thin and watery.

The portions drawn last coagulated much more rapidly than those drawn first. The former coagulated almost immediately after its removal from the body, whilst the latter required for its coagulation about thirty minutes.

The Fibrin was much softer than that of Terrapins in the normal condition.

Amount of blood obtained, about	1200 grains.
Solid constituents in 1000 parts of blood	114.56
" " " serum	34.90
" in serum of 1000 parts of blood . . .	32.02
Water in 1000 parts of blood	885.44
" " serum	965.10

1000 parts of blood contained—

Water	885.44
Blood-corpuscles (dried organic constituents)	78.16
Albumen, fatty and extractive matter	30.48
Fibrin	0.83
Fixed saline constituents	5.09

1000 parts of blood contained—

Moist blood-corpuscles	326.84	Water	245.13
		Solid constituents	81.71
Liquor sanguinis	673.16	Water	640.31
		Solid constituents	32.85

The bladder contained two fluidounces of clear, light yellow urine, having a slightly acid reaction. Specific gravity, 1002.

The amount of the urine had been greatly increased, and its character also chemically and physically, had been decidedly changed.

This subject will be more fully considered hereafter. The stomach was filled with vegetable food, which gave a slightly acid reaction.

42. Examination of a female salt-water Terrapin (*Emys terrapin*) which was deprived of food and drink for twenty-one days, then placed in a tub of fresh water, and abundantly supplied with Purslain (*Portulacca oleracea*), for thirty-three days, Sept. 17.

The serum was of an orange yellow color.

The clot was small, and like that of the blood of Terrapins under the same circumstances, soft.

The bladder contained about half a fluidounce of clear, light yellow urine, neutral to test paper and of low specific gravity.

The stomach and intestine presented the usual appearance of those of Terrapins which had been treated in a similar manner.

Solid constituents in 1000 parts of blood	113.92
" " " serum	28.97
" in serum of 1000 parts of blood	26.49
Water in 1000 parts of blood	886.08
" " serum	971.03

1000 parts of blood contained—

Water	886.08
Blood-corpuscles	87.43
Solid constituents of serum	26.49

1000 parts of blood contained—

Moist blood-corpuscles	349.72	Water	262.29
		Solid constituents	87.43
Liquor sanguinis	650.28	Water	623.79
		Solid constituents	26.49

Several other salt-water Terrapins which had been starved, and then transferred to fresh water, and supplied with vegetable food, were examined, and in every instance the results were similar to those recorded above. The following tables will give a condensed view of the effects of these experiments upon the constitution of their blood.

	(a). *Water and Solid Constituents in* 1000 *parts of Blood and Serum, and Amount of Blood obtained.*				*Fibrin and Fixed Saline Constituents.*		
	Water in 1000 parts of blood.	Water in 1000 parts of serum.	Solid constituents in 1000 parts of blood.	Solid constituents in 1000 parts of serum.	Amount of blood obtain'd.	Fibrin.	Fixed saline constituents.
					Grains.		
(1). Female *Emys terrapin* in normal condition having been captured twelve hours . .	845.28	956.17	154.72	43.83	1000.	4.15	10.74
(2). Female *Emys terrapin* deprived of food and drink 40 days	800.59	920.50	199.41	79.50	400.	5.26	10.74
(3). Female *Emys terrapin* which was deprived of food and drink twenty-one days, and then placed in fresh water and supplied with vegetable food 28 days	885.44	965.10	114.56	34 90	1200.	0.83	5.09
(4). Female *Emys terrapin* which was deprived of food and drink twenty-one days, and then placed in fresh water and supplied with vegetable food 33 days	886.08	971.03	113.92	28.97			

	(b.) *Moist Blood-corpuscles and Liquor Sanguinis in* 1000 *parts of Blood.*					
	MOIST BLOOD-CORPUSCLES.			LIQUOR SANGUINIS.		
	Moist blood-corpuscles.	Water of moist blood-corpuscles.	Solid constituents of moist blood-corpuscles.	Liquor sanguinis.	Water of liquor sanguinis.	Solid constituents of liquor sanguinis.
(1). Female *Emys terrapin* in normal condition	447.28	335.46	111.82	552.72	509.82	42.90
(2). Female *Emys terrapin* deprived of food and drink 40 days	500.00	375.00	125.00	500.00	425.59	74.41
(3). Female *Emys terrapin* deprived of food and drink 21 days, and then placed in fresh water and supplied with vegetable food 28 days	326.84	245.13	81.71	673.16	640.31	32.85
(4). Female *Emys terrapin* deprived of food and drink 21 days, and then placed in fresh water and supplied with vegetable food 33 days	349.72	262 29	87.43	650.28	623.79	26.49

By a careful comparison of the results of these experiments upon the Yellow-bellied Terrapins (*Emys serrata*) and the Salt-water Terrapins (*Emys terrapin*), we discover the following effects of starvation, thirst, and a change from animal to vegetable food.

The blood lost during starvation was rapidly restored, in amount, upon a vegetable diet.

The proportion between the moist blood-corpuscles and liquor sanguinis was not altered in any great degree.

In most instances, the solid constituents of the blood were less under a vegetable than under an animal diet.

The fixed saline constituents were diminished, because they do not exist in so large an amount in the Purslain (*Portulacca oleracea*) as in the Small Reptiles, Fishes, Crustaceans, and Mollusca, which constitute the ordinary food of these Chelonians.

In many instances, the shells of the Terrapins suffered from the deprivation of the fixed saline constituents. They were rendered much softer.

A deprivation of these constituents would prove much less injurious to cold-blooded animals than to warm-blooded.

In the latter, all the vital and chemical actions are rapid and incessant, and the integrity of the nervous and muscular systems depends in a great measure upon the supply of certain inorganic salts, as the phosphate of lime, which enter into their anatomical composition, and are absolutely essential to their existence and the performance of their functions. The action of the nervous system is always attended with a corresponding consumption of the inorganic as well as the organic elements.

In cold-blooded animals, the nervous system, circulatory and respiratory apparatus, are feebly developed, and the metamorphoses of the organic and inorganic elements of the tissues and organs are correspondingly slow.

The effects of a change of diet were strikingly exhibited in the alterations of the digestive apparatus.

The intestines of carnivorous Chelonians are small and contracted. See Fig. 8, which represents the digestive apparatus of the Snapping Turtle (*Chelonura serpentina*). In frugivorous Chelonians, as the Gopher (*Testudo polyphemus*), they are large and capacious. (See Fig. 9.)

This is not surprising, since vegetable substances are much more bulky, contain much less nutriment, and are much more slowly digested than an equal amount of animal food; and hence we might infer that the small intestines would be enlarged, so as to render them suitable for the digestion of vegetables.

In many cases, as already stated, the pancreas was affected with a cancerous disease. One of the principal offices of the pancreatic fluid, is to form an emulsion with fats, and I have found the pancreas to be always of a much smaller size in frugivorous animals than in the carnivorous. It is probable that the gland, not being normally exercised, degenerated in structure.

Another marked effect in a change of diet, was the production of dropsical effusions into the cellular tissue, the pleural and abdominal cavities. The vegetable albumen of the Purslain was in a much more diluted form than that derived from flesh, consequently a much larger amount of water was thrown into the circulation than with a diet of animal food. The kidneys, called upon to perform an unusual amount of work, were unequal to the task. Water, holding albumen in solution, accumulated in the cellular tissues and serous cavities. Gradually, however, the kidneys became accustomed to the change, and threw off more perfectly the large amounts of liquid. The Terrapins examined shortly after their removal to the tub of water, contained much more fluid in their tissues and serous cavities than those examined after the lapse of some time. This shows us the manner in which the characters of the blood are preserved. The watery elements absorbed along with the Purslain did not accumulate in the bloodvessels, but were

thrown off into the cellular tissue and serous cavities, and discharged by the kidneys. This shows that there is a tendency to a definite standard of concentration of the blood, and also to a definite proportion of its organic and inorganic constituents, which nature endeavors to maintain, however varied the conditions.

The effects of a change of diet upon the quantity, and chemical and physical constitution of the excretions of the kidneys, were strikingly illustrated in these experiments. The following table will present this in a clear light.

	Period of starvation and thirst.	Amount of urine excreted.	Specific gravity of urine.	Solid constituents of urine.	Reaction of urine.	Color of urine.
	Days.	Grains.		Grains.		
Female *Emys serrata*	17	442.3	1011.	11.33	Acid.	Turbid yellow.
" "	26	113.	1033.5	9.	"	Clear yellow, with chalky precipitates.
" "	29	223.1	1020.	10.396	"	Clear yellow, with precipitates.
" "	31	741.5	1017.5	29.36	"	Limpid yellow.
" "	38	890.6	1017.6	37.34	"	Yellow, with heavy precipitates.
Male "	49	300.	1019.4	13.02	"	Yellow, with precipitates.
Female *Emys terrapin*	40	300.	1015.	10.4	"	Clear yellow.
" "	43	70.			"	Cream-colored like pus.
" "	57	130.		8.05	"	Clear yellow.
Female *Emys terrapin*, deprived of food and drink 21 days, and then placed in fresh water and supplied with vegetable food 28 days. . . .		840.	1002.	3.40	Slightly acid.	Limpid light-yellow.
Emys serrata, starved 30 days, and then supplied with water and vegetable food 42 days. . .		2150.	1000.	5.	Neutral.	Limpid light-yellow.
Emys serrata, starved 30 days, and then supplied with water and vegetable food 60 days. . .		2160.	1004.	18.64	Neutral.	Limpid light-yellow.
Emys serrata, starved 30 days, and then supplied with water and vegetable food (purslain) 88 days.		2000.	1000.	1.	Neutral.	Limpid light-yellow.

From this table we see that the effect of the change of diet was to render the urine much more abundant, and to alter entirely its specific gravity and chemical reactions.

This subject, however, will be considered in its important bearings, when we come to the investigation of the kidneys and their excretions.

CHAPTER V.

OBSERVATIONS UPON THE ALIMENTARY CANAL AND DIGESTION OF ALBUMEN AND FLESH.

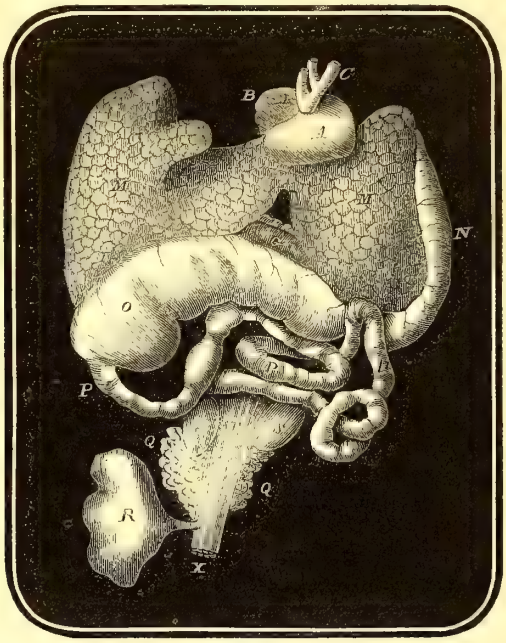
In many cartilaginous fishes, as the Stingray (*Trygon sabina*), the extent of surface over which the digested aliment is spread, is increased by a spiral valve which winds in close turns, from the pyloric to the anal extremity of the capacious intestine. By this remarkable arrangement, the apparently short intestine possesses an exceedingly enlarged surface of mucous membrane.

Fig. 19 represents the viscera and impregnated uterus of a Stingray (*Trygon sabina*), reduced to half its diameter.

The intestinal canal of Ophidians, is but slightly convoluted; its length is generally about equal to that of the body.

Fig. 21 represents the viscera of the Corn Snake (*Coluber guttatus*), reduced to half its diameter.

Fig. 8.



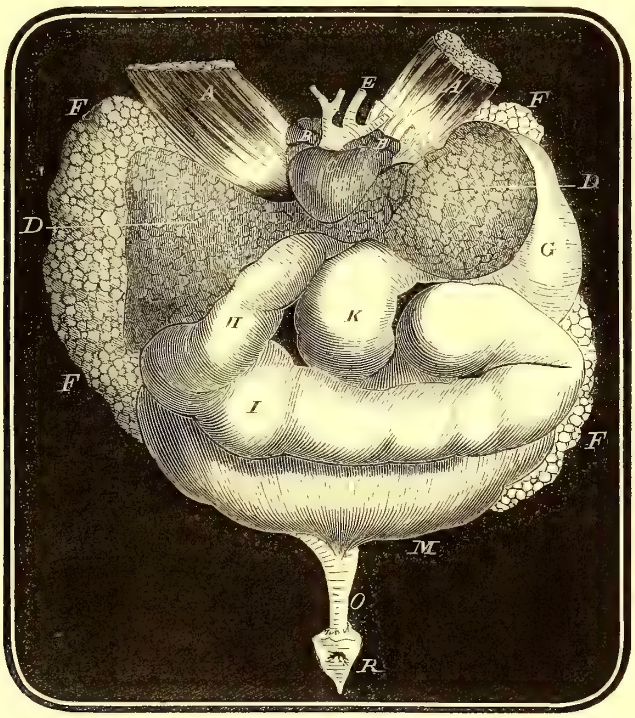
Viscera of Snapping Turtle (*Chelonura serpentina*), a carnivorous chelonian, reduced to one-half diameter. A. Ventricle of heart. B. Auricle of heart. M, M. Liver. N. Stomach. G. Duodenum; a small portion of the pancreas is seen in contact with the superior surface of the duodenum. P, P, P. Small intestines, which suddenly expand into the large intestine. O. Large intestine, filled with shells of crustacea, and fragments of grass and leaves. T. Rectum, S, S. Testicles. Q, Q. Kidneys. R. Bladder, partially filled with light yellow urine; the bladder communicates with the cloaca. X. Divided extremity of the large intestine, called, at this position, the cloaca.

The intestinal canal of the Congo Snake (*Amphiuma means*) resembles, in many respects, that of Ophidians (see Fig. 20).

The intestinal canal of carnivorous chelonians, as the Yellow-bellied Terrapin (*Emys serrata*), Chicken Terrapin (*Emys reticulata*), Salt-water Terrapin (*Emys terrapin*), and Snapping Turtle (*Chelonura serpentina*), is shorter and much less capacious than that of the graminivorous Gopher (*Testudo polyphemus*).

A comparison of the viscera of a carnivorous chelonian, as the Snapping Turtle (*Chelonura serpentina*) (Fig. 8), with the viscera of a graminivorous chelonian, as the Gopher (*Testudo polyphemus*) (Fig. 9), shows the modifications by which the alimentary canal is adapted to the habits and food of animals.

FIG. 9.



Viscera of the Gopher (*Testudo polyphemus*), a graminivorous chelonian, reduced to one-half diameter. A, A. Muscles. B, B. Auricles of heart. C. Ventricle of heart. F, F, F, F. Lungs; the lungs of this chelonian are very extensive. D, D. Liver. G. Stomach. H. Inferior portion of the small intestine. I, K. The large intestine, filled with grass and vegetable matters. M. Bladder: the bladder of the Gopher is capacious, and in medium-sized individuals of this species, often contains five fluid ounces of urine; the bladder empties its contents into the lower portion of the large intestine, or cloaca. O. Cloaca. R. Tail and anus: the tail is remarkably small and short in the *Testudo polyphemus*.

In all the gophers that I have examined, the stomach and small intestines were completely empty; while the colon and rectum, which are developed to an enormous extent, were packed with grasses and leaves. The vegetable food contained in the colon and rectum of medium-sized gophers, often amounted to several thousand grains.

These animals are able to do without food and drink much longer than carnivorous chelonians, because the wastes of the solids and fluids are supplied from this capacious storehouse of nutritive materials.

When carnivorous terrapins were starved for a length of time, and then fed upon

vegetable food (purslain), the intestinal canal gradually became much enlarged, and resembled, in some respects, that of the gopher.

The colon and rectum of carnivorous chelonians generally contain the shells of invertebrate animals, and parts of leaves and grasses. During starvation, all the organic constituents of the shells gradually disappear, and nothing remains in the colon but white chalk-like masses, which I determined, in several instances, to be carbonate and phosphate of lime. The intestines, from the stomach to the anus, never contained any large amount of bile, showing that it was absorbed.

The stomach of cold-blooded animals gives an acid reaction during starvation and digestion. During starvation, the small intestines give, in many places, a feeble acid, and in others a neutral reaction. When fed upon vegetable substances, the reaction from the stomach to the anus was acid.

Table showing the length of the Alimentary Canal in various Animals.

	Weight of the body.	Length of the alimentary canal.
FISHES.	Grains.	Inches.
Trygon sabina (Stingray)	16,400	12
Zygæna malleus (Hammerhead Shark)	54,350	28
Lepisosteus osseus (Garfish)	22,303	30
Lepisosteus osseus (Garfish)	52,110	28¾
REPTILES.		
Menopoma Alleghanensis		24
Rana catesbæana (Bullfrog)	9,800	34
Heterodon niger (Black Viper)	4,620	26
Psammophis flagelliformis (Coachwhip Snake)	5,141	42
Coluber guttatus (Corn Snake)	9,600	54
Coluber constrictor (Black Snake)	5,100	36
Crotalus adamanteus (Rattlesnake)	6,180	42
Alligator Mississippiensis (Alligator), female	211,940	147
Alligator Mississippiensis (Alligator), male	76,507	60
Chelonia caretta (Loggerhead Turtle)	36,985	102
Chelonura serpentina (Snapping Turtle)	16,235	46
Emys reticulata (Chicken Terrapin)	8,400	38
Emys serrata (Yellow-bellied Terrapin)	27,172	66
Emys serrata (Yellow-bellied Terrapin)	14,400	54
Emys serrata (Yellow-bellied Terrapin)	23,100	60
Trionix ferox (Soft-shelled Turtle)		48
Testudo polyphemus (Gopher)	45,500	78
Testudo polyphemus (Gopher)	18,368	54
BIRDS.		
Tantalus loculator (Wood Ibis)	39,375	84
Tantalus loculator (Wood Ibis)	37,625	84
Ardea nycticorax (Night Heron)	10,095	90
Cathartes atratus (Black Turkey-Buzzard)	31,937	60
Syrnium nebulosum (Barred Owl)	10,580	36
Ortyx Virginiana (Quail)	2,760	40
Meleagris gallopavo (Wild Turkey)	36,312	72
Meleagris gallopavo (Wild Turkey)	28,875	68
MAMMALS.		
Didelphis Virginianus (Opossum)	18,812	51
Common Cat	35,000	64
Pointer Dog	247,126	138
Procyon lotor (Raccoon)	47,787	216
Procyon lotor (Raccoon)	54,735	180
Procyon lotor (Raccoon)	59,110	180
Sciurus Carolinensis (Gray Squirrel)	6,960	120
Sciurus capistratus (Black Fox Squirrel)	14,710	123
Cervus Virginianus (fœtus of Deer)	26,935	234
Common Sheep	385,000	1,056

Length of the Stomach, Small Intestines, Colon, and Rectum.

	Length of stomach.	Length of small intestines.	Length of colon and rectum.
	Inches.	Inches.	Inches.
Trygon sabina (Female Stingray)	$3\frac{1}{2}$	$8\frac{1}{2}$	
Zygæna malleus (Hammerhead Shark)	10	28	
Menopoma Alleghanensis (Hellbender)	$3\frac{1}{2}$	16	6
Rana catesbæana (Spring Frog)	4	30	
Chelonura serpentina (Snapping Turtle)	4	32	10
Testudo polyphemus (Gopher)	8	24	46
Testudo polyphemus (Gopher)	6	18	30
Common Cat		54	10
Didelphis Virginianus (Opossum)		38	18
Common Sheep		864	192

Length of the Bodies and Alimentary Canals of Ophidians.

	Length of animal.	Length of the alimentary canal.
	Inches.	Inches.
Heterodon niger (Black Viper)	32	26
Psammophis flagelliformis (Coachwhip Snake)	68	42
Coluber guttatus (Corn Snake)	54	54
Coluber constrictor (Black Snake)	54	36
Crotalus adamanteus (Rattlesnake)	48	42
Water Snake	40	50

Digestion of Albumen and Flesh.

The process of digestion has been the subject of numerous careful and laborious investigations, and after the researches of Spallanzani, Magendie, Tiedemann, Gmelin, Prout, Beaumont, Mulder, Dumas, Liebig, Blondot, Bernard, Lehmann, Bidder and Schmidt, and many others, it seems impossible that it should still remain in obscurity.

It has been the prevailing opinion of authors, that flesh, and the protein bodies generally, are digested entirely in the stomach. This fact, however, has lately been denied by physiologists of the highest authority. By recent experiments, Bidder and Schmidt have convinced themselves, that one of the important offices of the intestinal juice, is to dissolve and render fit for absorption, not only starch, but also flesh and other protein bodies. They assert that the intestinal juice not only metamorphoses starch with as great rapidity as the salivary and pancreatic fluids, but also that the intestine exerts as powerful a digestive influence on flesh and albumen as the stomach. Frerichs, on the other hand, has been unable, in his experiments, to detect any change exerted by the intestinal juice upon the protein elements of the food. Protein bodies, gelatinous substances, fat and starch, remained unchanged, and he denies positively that the intestinal juice has any action as a direct digestive agent.

Professor Lehmann, in a series of experiments upon the intestinal fluid collected from a loop of a gut in a human being with a fistulous opening into the small intestine, found that it possessed in a high degree, the power of converting starch

into sugar; whilst protein bodies and fats were not affected in any appreciable manner. Professor Lehmann, however, attaches little importance to these experiments performed by himself, from the fact that the fistulous opening was in the lower portion of the ileum, and probably near the cæcum. He adopts the experiments of Bidder and Schmidt, and by an argument drawn from the amount of gastric juice secreted in a given length of time, and the amount of protein substances which it is capable of digesting, concludes that a large portion of flesh and albumen, and the other protein bodies, pass out of the stomach undigested, and are finally dissolved by the intestinal fluid. According to Professor Lehmann, the amount of gastric fluid secreted by a dog in 24 hours, equals one-tenth the weight of the whole body. 100 grains of recent gastric juice are capable of dissolving from 3 to 5 grains of coagulated albumen. A dog needs daily, for the perfect maintenance of all the physiological functions, 50 grains of flesh (containing 10 grains of albuminates) for every 1000 grains of its weight. It secretes, however, only 100 grains of gastric juice for every 1000 grains of its weight, only one-half the amount capable of dissolving the albuminates of the flesh. Hence a large portion of the protein bodies must pass out of the stomach undigested.

Careful experiments have shown that the gastric juice is deprived in the duodenum, of its free acid; and, with it, of its power of digestion by the bile and pancreatic fluid. Hence other fluids must flow into the intestines, which are capable of dissolving the protein bodies.

The only method of deciding accurately upon the truth of these conclusions, drawn by Prof. Lehmann from the preceding argument, is to appeal to the physico-chemical process of digestion, as it is performed in a normal condition in the animal economy.

I have enjoyed numerous opportunities of examining the contents of the stomachs of Fishes, Reptiles, Birds, and Mammals in every stage of the digestive process, and have never discovered undigested particles of flesh in the small intestines. The following observations were made during the prosecution of various researches upon the blood, urine, relative weights of the organs, comparative anatomy and minute structure of the organs of different animals, without any reference whatever to the maintenance of an hypothesis.

The stomach of an Alligator (*Alligator Mississippiensis*) contained the bones, teeth, hoofs, and hair of a pig. The flesh had been entirely digested, leaving the bones as clean as those of a prepared skeleton.

In the stomach of other alligators, we have found fishes, snakes, crabs, &c., in different stages of digestion—some but slightly acted upon by the gastric juice, others partially dissolved; whilst of others, little more than their bones remained.

The stomach of a Bullfrog (*Rana catesbœana*), which had been captured twenty-four hours, contained several Crawfish (*Astacus Bartoni*), and a slender Grass Snake (*Tropidonotus ordinatus*), about three feet in length. Although this food had been swallowed for more than twenty-four hours, only the exterior parts of the body of the serpent showed the evidences of the action of the gastric juice, and the shell of the invertebrate animals was of a red color, resembling that which they assume after they have been acted upon by boiling water.

In the stomachs of serpents we have found smaller serpents, lizards, and mice in all stages of digestion, whilst the small intestines contained not a particle of flesh.

These observations were also verified by an examination of the contents of the stomachs of fishes, carnivorous birds—as buzzards, hawks, cranes, herons, &c.; and also of carnivorous mammals—as raccoons and dogs.

If one-half of all the flesh received into the stomach passes into the small intestines, and if the process of digestion is, according to the statement of Bidder and Schmidt, as slow as that in the stomach, why is it that its presence always eluded observation when the intestinal canal was laid open? Especially in the case of animals which swallow their prey whole, without any mastication, it is difficult to see how portions of flesh could pass out of the capacious stomach into the contracted intestine, without being evident to the observer? All the observations I have thus far made, convince me that flesh is entirely digested in the stomach.

Another fact worthy of note is, that in the stomach of all animals, whether cold or warm-blooded, which I have examined whilst the process of digestion was going on, the amount of fluid containing the digested matter in solution, was exceedingly small, oftentimes amounting to only a few drops, and in many cases, especially amongst cold-blooded animals, it appeared to be almost entirely absent. This proves that, in the normal process of digestion, the matter dissolved by the gastric juice is almost immediately absorbed or passes into the duodenum.

As far as my observations have extended, a solution of the albuminous matters (chyme) does not often accumulate in the stomach. This accords with the results of the experiments of Dr. Samuel Jackson, Professor of the Institutes of Medicine in the University of Pennsylvania.

This fact shows the fallacy of the inference founded on the amount of flesh which can be digested by a given quantity of gastric juice out of the body. The natural process is far different from the artificial. A portion of gastric juice dissolves a definite amount of flesh, and the solution is then absorbed, or passes out into the small intestines. Another portion of gastric juice is secreted, and acts upon the fresh exposed surface of the flesh, and the products are in turn absorbed. It is evident that this process is far more energetic than that of artificial digestion, and consequently the one cannot be the measure of the other.

Even granting that artificial and normal digestion are precisely similar as far as the rapidity of their actions is concerned, how is it possible to determine the amount of gastric juice secreted by the stomach in a given time, when absorption is almost as rapid as secretion. In the consideration of the digestion of protein bodies, this fact has been left entirely out of view.

The absorption and passage of the digested matters, out of the stomach, immediately after their solution, is true also of graminivorous and frugivorous animals. I have examined the stomachs of numerous squirrels, rats, and birds fed upon grain, acorns, nuts, and berries, and in almost every instance there was no fluid that corresponded to the chyme. Even in those animals which subsist upon grasses and green buds and leaves, which contain a larger amount of fluid, the contents of the stomach are comparatively dry. Almost every one has it in his power to verify

these observations, by simply visiting the butcher pens, and examining the contents of the stomachs of cows, sheep, &c.

Amongst cold-blooded animals, the only frugivorous species which I was able to examine, was the Gopher (*Testudo polyphemus*). In this the grasses and vegetable matters appear to be principally digested in the colon, which is enlarged into a receptacle for food, thirty inches in length and four inches in circumference. (See Fig. 9.) In one instance, after starvation for thirty days, the undigested vegetable contents of the colon and cæcum amounted to 1460 grains. The Gopher, as we have said in a previous chapter, has the power of retaining in its intestines vegetable food, which neither digests nor putrefies, though it rapidly decomposes when removed from the body.

CHAPTER VI.

COMPARATIVE ANATOMY AND PHYSIOLOGY OF THE PANCREAS.

Among the invertebrates no lymphatic system has been discovered, and the existence of a pancreatic gland has not as yet been satisfactorily shown.

Siebold considers two thick walled cæca, lined with ciliated epithelium, and opening into the beginning of the stomach, in many Rotatoria, a rudimentary pancreas. Hunter, Grant, Owen, Siebold, and Rymer Jones, consider the pale-yellow ramified tubes, which, in many species of Cephalopoda, are appended to the hepatic ducts as true representatives of the pancreatic glands of the higher animals. These, however, have not been definitely proved to be pancreatic glands, for no comparative anatomist or physiologist has as yet described the special character and offices of their secretion.

In the four great classes of vertebrate animals the circulatory system is completely separated from the digestive cavity, all the organs are highly developed, and the existence of a special system of absorbents appears to be absolutely necessary for the preservation of the integrity of the animal fluids, and also for the absorption of fatty matters, which are of great importance in the maintenance of animal temperature.

In Fishes, the development and perfection of the pancreas corresponds in no degree with the position occupied by different individuals in the classification of naturalists. The most superficial examination of the gland under consideration will show that many animals, of an exceedingly simple structure, often have individual organs more highly developed than those which stand far above them in physical and mental constitution. Thus in the lowest orders of the cartilaginous fishes, the Cyclostomi and Plagiostomi, this gland resembles, in all respects, that of the more highly organized mammals. In the Sturiones, its structure is somewhat simplified, and, in the majority of Osseous Fishes, it is reduced to its rudimentary form, consisting of cæca, varying in number in different species, and opening into the duodenum below the circular valve of the stomach, whilst in others, as observed by Cuvier in the Conger Eel, Pike, and Carp, and by Müller in the *Ophisurus serpens,* it is intimately associated with the internal mucous membrane, consisting of simple follicular depressions lined with the peculiar cells constituted to secrete the pancreatic fluid. It cannot, therefore, be asserted as a universal rule, without any exception, that there is a regular progression in the development of the different organs in animals, corresponding to the position which they occupy in the scale of creation. This may be illustrated by comparing together the rudimentary pancreas

of the Plaice, Fig. 10; the pancreas of the Stingray (*Trygon sabina*), Fig. 13; the pancreas of the Hammerhead Shark (*Zygæna malleus*), Fig. 22; and the pancreas of the Garfish (*Lepisosteus osseus*), Fig. 11.

It matters not whether we view the pancreas in its earlier stages of development in the higher animals or in its permanent condition in many of the Osseous Fishes, its structure is the same. By classifying this organ according to its development in fishes we have an exact history of the changes which occur during its development in the higher animals. The permanent forms of the pancreas of the former are but transitory conditions, forming the stages in the development of this organ in the latter. According to Müller, Weber, and Wharton Jones, in higher animals which have a perfect pancreas, its development, like that of the salivary glands, commences by a simple diverticulum, or cæcum, from the walls of the duodenum. This subdivides into bud-like processes. As the development of the gland advances, the canal and its branches become more and more ramified and subdivided, until the compound racemose lobulated gland is formed. Precisely the same stages of development in a permanent form are discernible in the different orders, genera, and species of fishes.

Mere cells or follicular depressions in the mucous membrane of the small intestines, according to the observations of Cuvier, Müller, and Solly, perform the offices of the pancreas in several species, as the *Hippoglossus rondeletus*, Conger Eel, Pike, and Carp, and *Ophisurus serpens*.

In the *Ammodytes tobianus* there is a single cæcum prolonged into a pouch, representing this gland in its rudimentary condition. Several species of Plaice have two, whilst others have three, like the River Perch and Common Loach, whilst the *Platessa oblonga* has four of these cæcal pouches, which open into the pylorus and duodenum. This form of the pancreas is seen in the following figure :—

Fig. 10.

Rudimentary pancreas of the Plaice (*Platessa oblonga*) reduced to one-half diameter. A. Stomach. B. Pyloric extremity of stomach. C, C, C, C. Pancreatic cæca opening into the small intestine below the pyloric valve of the stomach. F. Small intestine. G. Large intestine. S. Spleen.

Five of these cæca occur in *Salmo spirlingulus*, six in *Perca lucioperca* and *Sargus annularis*, seven to eight in the Bass (*Corvina ocellata*), and ten to thirty or more in many Salmons and Herrings, and from eighty to ninety in the Common Salmon.

In *Gadus* and *Scomber*, the number is greatly augmented, and the complexity of the gland increased by the division of the cæca. In *Scomber thynnus* four large trunks arise from the intestine, and divide into branches, each of which subdivide and terminate at length in a tuft-like fasciculus of narrow tubular cæca.

In the salt-water Garfish (*Lepisosteus osseus*) of Georgia, the pancreas is situated with its superior convex border in contact with the inferior concave border of the liver, which resembles in shape and appearance this organ in serpents. The inferior border is in contact with the spleen. Upon the exterior it consists of numerous short cæca, which radiating inwards unite together forming several branches, which again unite and constitute one short duct, having a diameter almost equal to that of the small intestine into which it opens.

The duct branches of cæca generally contain, especially after a meal of fish, a cream-like fluid, which, under the microscope, is found to be a true emulsion, containing innumerable minute globules of oil in a transparent fluid. The large opening of the duct of the pancreas is so situated, just at the bend of the duodenum, that all the digested food, after passing the stomach, must be submitted to the influence of its secretion and much passes into the duct and cæca. All the oleaginous matter must, therefore, be brought into contact with the pancreatic juice, and in this manner an emulsion is formed and prepared for absorption. The emulsion is not found in the stomach above the opening of the duct of the pancreas, but exists in greatest abundance in its immediate vicinity and within the cæca.

The structure of this gland in the fresh-water Garfish of the swamps of Georgia, is constructed on a similar plan; its cæca, however, are longer, and the branches more distinct. The duct, branches, and cæca, contained, in every instance after a full meal, a similar fatty emulsion.

Fig. 11 represents the viscera, with the structure and position of the pancreas of the fresh-water Garfish.

This organ is very large in the Swordfish (*Ziphias gladius*). Professor Grant states, in his *Lectures upon Comparative Anatomy*, that, in the Swordfish, this organ is very large, and that it consists of innumerable small cæca connected together by cellular tissue, in which ramify the capillary vessels. These cæca form a reniform mass which is surrounded with a muscular tunic and the peri-

Fig. 11.

Viscera of a Fresh-Water Garfish reduced one-half diameter. B. Rough outline of the head. C, C. Pectoral fins. A. Heart. F. Superior portion of the lung. M. Lung. T. Inferior portion of the lung. The lung of the Garfish is a capacious fibrous sac which opens by a short trachea, high up in the throat, and extending nearly the whole length of the abdominal cavity, terminates within a short distance of the anus. It lies between the posterior surface of the liver and the anterior surface of the kidneys. When removed from the abdominal cavity, and fully inflated, its diameter is about equal to one-half of that of the fish. In many respects its structure resembles that of the *Amphiuma means* and other doubtful reptiles. L. Liver. N. Stomach. P. Pancreas composed of numerous cæca. S. Spleen situated in a convolution of the small intestines. In many individuals I have found two spleens. R. Inferior portion of intestinal canal. K. Anus. X. Anal fin.

toneum. When opened, the innumerable component cæca are found to be formed by the successive divisions of the single great duct into which they all pour their secretions into the duodenum immediately below the pyloric valve.

In the Sturgeon, the structure of the pancreas is similar to that of the *Ziphias gladius*. The hundreds of cæca ramified from one common duct are inclosed in a muscular and peritoneal coat. The contraction of the muscular tunic compresses the cæca and forces their secretion into the intestinal canal. The excretory duct opens close to the pyloric valve and the termination of the *ductus communis choledochus*.

In the Eel, Pike, and fresh-water Trout, we find a yellowish-white compact glandular pancreas, having from two to three excretory ducts, which are frequently accompanied in their course to the intestine by the biliary ducts. In the Trout and some others there exist both pyloric appendages and a compact pancreatic gland.

In the Hammerhead Shark (*Zygæna malleus*), we find an elongated, narrow, flattened, light yellow, compact pancreas, with little lobulation. (See Fig. 22.)

In the Stingray (*Trygon sabina*), this organ is of a yellow color, and well defined, lobulated form, resembling in all respects the perfectly-developed pancreas of the Mammalia and other vertebrates.

The following figures represent the position and appearance of the pancreas of the Stingray (*Trygon sabina*).

FIG. 12. FIG. 13.

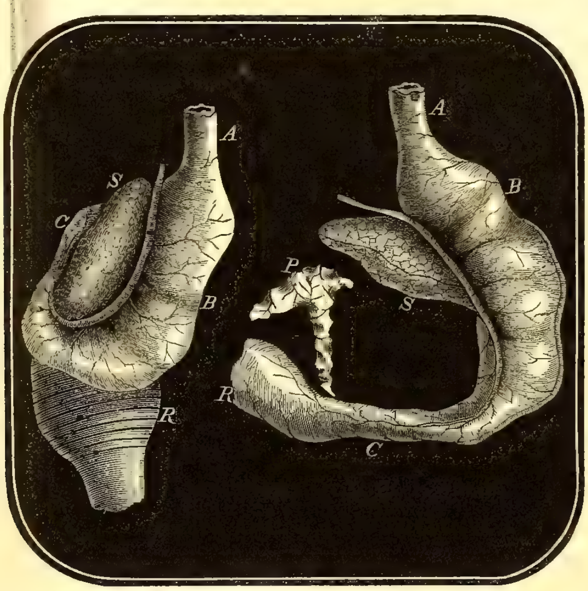


FIG. 12.—Position of the stomach, spleen, and intestine of the Stingray (*Trygon sabina*) after the removal of the liver. Reduced one-half diameter.—A. Inferior portion of the œsophagus expanding into the stomach. B. Stomach. S. Spleen. C. Duodenum, or commencement of small intestine. R. Intestine with spiral valve; the dark lines mark the turns of the valve.

FIG. 13 represents the stomach and spleen of the *Trygon sabina* turned over to one side, thus exposing the pancreas. Reduced one-half diameter.—A. Inferior portion of the œsophagus expanding into the stomach. B. Stomach. C. Small intestine, or duodenum. S. Spleen. P. Pancreas, presenting the appearance of this organ in the higher animals.

The pancreas of the Doubtful Reptiles assumes the appearance presented by that of the Stingray, Shark, and warm-blooded animals.

In the *Menobranchus maculatus*, it is an irregularly-shaped gland, having four principal lobes diverging from each other at right angles, thus presenting a stellate arrangement.

Fig. 14.

Stomach, spleen, and pancreas of the *Menobranchus maculatus*. Reduced one-half diameter.—A. Stomach. S. Spleen. P. Pancreas. D. Small intestine.

The pancreas of the Hellbender (*Menopoma alleghanensis*) is a long, delicate, light yellow gland, which commences near the pyloric extremity of the stomach, and extends down along the duodenum and small intestine for about three inches. Its inferior portion is more expanded than the superior. (See Fig. 24.) The pancreas of the Congo Snake (*Amphiuma means*) is similar in structure and appearance to that of the *Menopoma alleghanensis*, with the exception that it is broader and thicker. (See Fig. 23.)

In the Batrachia, the pancreas presents a developed appearance, and generally commences by a small slender lobe at the pyloric extremity of the stomach, and, passing downwards and forwards, expands into a broad lobulated mass. As in many other cold-blooded animals, it is not in contact with the spleen.

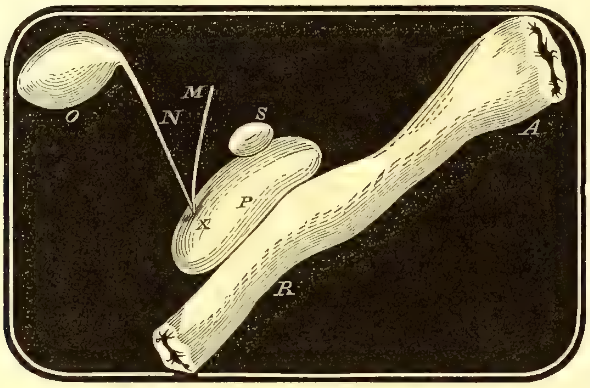
I have examined many American Ophidians,[1] and in each the pancreas is a compact, ovoid gland, often kidney-shaped, situated in contact superiorly with the

[1] For example, Banded Rattlesnake (*Crotalus durissus*), the Water Rattlesnake (*Crotalus adamanteus*), Ground Rattlesnake (*Cratalophorus miliarius*), Water Mokeson (*Trigonocephalus piscivorus*), Copperhead (*Trigonocephalus contortrix*), Hog-nose Viper (*Heterodon platyrhinos*), Black Viper (*Heterodon niger*), Grass Snake (*Tropidonotus ordinatus*), Water Snake (*Tropidonotus fasciatus*), Green Snake (*Leptophis æstivus*), Coachwhip Snake (*Psammophis flagelliformis*), Indigo Snake (*Coluber couperi*), Chicken Snake (*Coluber quadrivittatus*), Corn Snake (*Coluber guttatus*), Black Snake (*Coluber constrictor*).

gall-bladder, and inferiorly attached to the duodenum. The spleen, which is very small in these animals, is attached to the antero-superior surface of the pancreas. The hepatic and cystic ducts perforate the substance of the pancreas, and, uniting with its duct, enter the duodenum.

The following figure represents the position and appearance of these viscera in the Water Snake (*Tropidonotus sipedon*).

Fig. 15.

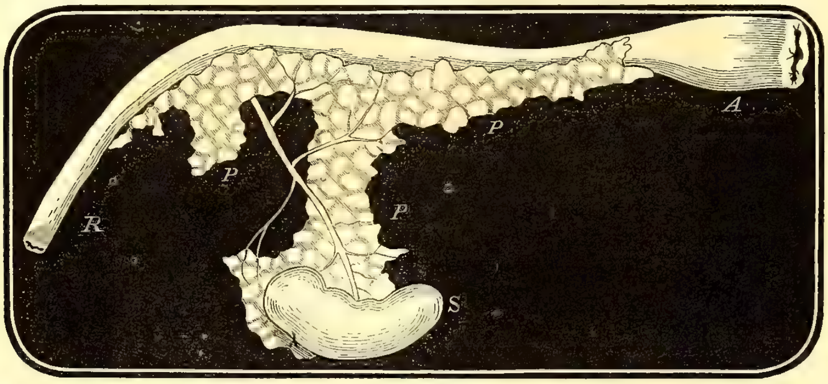


Spleen and pancreas of Water Snake (*Tropidonotus sipedon*). Natural size.—A. Inferior portion of the stomach contracting into the duodenum. R. Small intestine. P. Pancreas, a compact ovoid gland. S. Spleen attached to the anterior superior surface of the pancreas. By comparing the spleen of this serpent with those of other animals (as in Figs. 10, 12, 13, 14, 16, 17, 18, 22, 23, and 24), we see that this organ is remarkably small in Serpents. O. Gall-bladder. N. Cystic duct passing down and joining the hepatic duct, M, just where it perforates the pancreas. M. Inferior portion of the hepatic duct. X. Point at which the cystic and hepatic ducts perforate the pancreas.

In the carnivorous Chelonia, the pancreas is a large, well-developed, light-yellow, lobulated gland.

In the Soft-shelled Terrapin (*Trionyx ferox*), it commences opposite the pyloric valve of the stomach. The principal lobe extends down along the small intestine about three inches. At the inferior portion it sends off two lobes—the inferior one short and broad, the superior longer—and, passing downwards, comes in contact with the spleen, and passes along the anterior surface of this organ.

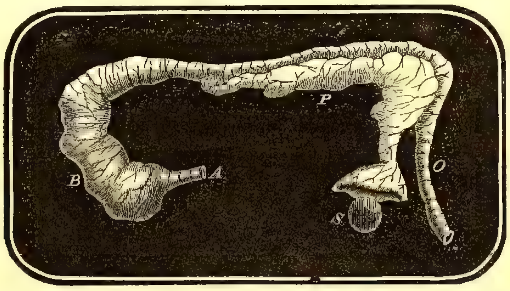
Fig. 16.



Pancreas of a carnivorous Chelonian (*Trionyx ferox*), Soft-shelled Turtle. Reduced one-half diameter.—A. Inferior portion of stomach contracting into small intestine. P, P, P. Pancreas composed of numerous lobules. S. Spleen. R. Small intestine.

The structure, position, and appearance of this gland do not differ in any essential respect in the Alligator Cooter (*Chelonura serpentina*), Loggerhead Turtle (*Chelonia caretta*), Salt-water Terrapin (*Emys terrapin*), Chicken Terrapin (*Emys reticulata*), Yellow-bellied Terrapin (*Emys serrata*), and other carnivorous Terrapins. The following figure represents the pancreas of the Yellow-bellied Terrapin (*Emys serrata*).

Fig. 17.

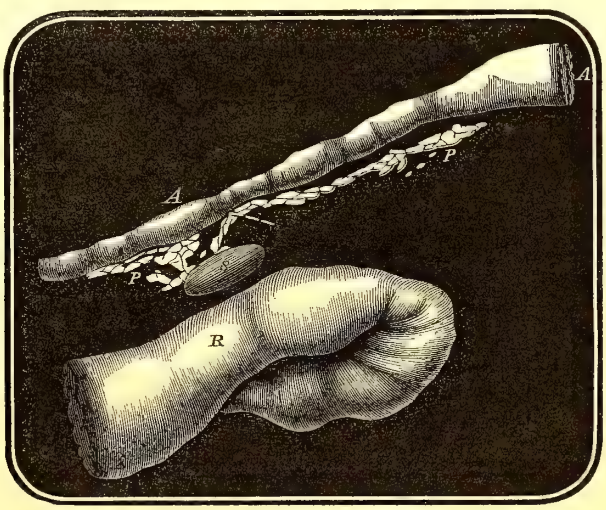


Pancreas of a carnivorous Chelonian (*Emys serrata*). Reduced one-half diameter.—A. Inferior portion of the œsophagus expanding into the stomach. B. Stomach. P. Pancreas. S. Spleen. O. Small intestine.

In the Gopher (*Testudo polyphemus*), which is the only graminivorous Chelonian in Georgia, the size and appearance of the pancreas are far different.

It is a long, slender, delicate gland, consisting of several thin slender lobes, subdivided into numerous small lobules. Its size is far smaller than that of carnivorous Chelonians. The reason of this will be readily understood when we consider the functions of the gland.

Fig. 18.



Pancreas of a graminivorous Chelonian (*Testudo polyphemus*), Gopher. Reduced one-half diameter.—A, A. Inferior portion of stomach and small intestine. P, P. Pancreas. S. Spleen. R. Large intestine, which contains grass.

A comparison of Figs. 16, 17, and 18, illustrates the fact that the pancreas of carnivorous Chelonians is larger than that of the graminivorous ones.

In Birds, the pancreas is a conglomerate gland, generally of large size, invariably lodged within a loop formed by the duodenum, and generally consists of two por-

tions or lobes, united by a slender isthmoid portion. In some individuals it is single, and in others consists of three lobes. From each lobe an excretory duct is given off, which terminates separately in the intestine near the opening of the biliary canals. The color and appearance are similar to those of the well-developed pancreas in all animals, cold or warm-blooded, and so constant in this respect are the different glands in vertebrate animals that any one familiar with comparative anatomy and physiology can distinguish them at a glance.

The pancreas of the omnivorous and carnivorous Mammalia resembles, in appearance and structure, that of Man; its secretion enters the duodenum at the same point as that of the liver. In the Apes, the Ruminantia, and most Carnivora and Rodentia, it has but one duct which usually unites with the biliary. In some animals—as the Horse, Hog, Otter, and Beaver—it has two ducts, one of which unites with the biliary duct, and the other enters by itself, further behind, into the duodenum. In the Rabbit, the biliary and pancreatic ducts are separated from each other by a considerable interval.

The pancreas of all the carnivorous Mammalia which I have thus far examined is much larger than that of the frugivorous ones. This illustrates an important physiological fact, which will be shown by numerous comparative weights of the organ accurately ascertained.

Having considered the development, structure, and comparative anatomy of the pancreas in the four great classes of vertebrate animals, we shall next consider its use in the animal economy.

Although Mayer, Magendie, Tiedemann, Gmelin, Leuret, Lassaigne, and other physiologists and chemists had investigated the physical and chemical properties of the pancreatic fluid, still one of its important offices was entirely unknown until the researches of M. Cl. Bernard[1] demonstrated that it is indispensable for the formation of chyle and the absorption of fatty matters. Previous to this discovery, it was considered similar to the fluid secreted by the salivary glands, and its principal use was affirmed to be the conversion of starch into glucose. The investigations of M. Cl. Bernard demonstrated that the limpid chyle (formerly called vegetable chyle) is the product of the digestion of materials which contain no fatty matters, and the white chyle (called formerly animal chyle) contains fatty matters in the state of an emulsion, and the lymphatics of the mesentery are found to contain a white milky fluid only after the absorption of fatty matters, and that this emulsion and modification of the fatty matters were effected by the agency of the pancreatic juice. These conclusions were derived from the results of numerous ingenious experiments.

If Dogs are fed upon oleaginous matters, and killed at different periods, oil will be found unaltered until it comes in contact with the pancreatic fluid, and if the pancreatic ducts be tied, all alteration is prevented, and the oil remains transparent.

The most conclusive and beautiful of all Dr. Bernard's experiments were performed upon the Rabbit. In this animal, the pancreatic duct opens into the intes-

[1] Annales des Sciences Natur. Sept. 1848.

tine very low down, from six to fourteen inches below the hepatic duct, and if fatty matter be introduced into the stomach, and the animal killed in three or four hours, it will be found to have become an emulsion, and the lymphatics of the mesentery filled with white chyle only below the opening of the pancreatic duct. M. Cl. Bernard further showed that if fatty bodies be exposed to the pancreatic fluid, out of the body, a complete emulsion is formed, and, if it be allowed to remain long enough, the fatty substances will be decomposed into glycerine and fatty acids, and, in the case of butter, butyric acid. Parallel experiments instituted with other fluids—as bile, saliva, gastric juice, serum of the blood—produce no such effects on fatty bodies.

It was probably supposed that fat was, in the animal economy, resolved into glycerine and fat acids. This process, however, would be very complicated, and involves many difficulties, and it is more reasonable to conclude that the action of the pancreatic juice is limited to the formation of an emulsion, which is nothing more than the mechanical division of the fat into minute globules, coated with a thin film of the albuminoid elements of the pancreatic juice. That this is really the case in living animals, I enjoyed many opportunities of rendering apparent, whilst examining the pancreas of the Garfish (*Lepisosteus osseus*). In this fish, the duct of the pancreas has a diameter almost equal to that of the intestine, and is so situated that all the digested matters which pass out of the stomach must come in contact with its secretion, and often pass, in considerable amount, into the duct and cæca of the gland. When the emulsion is squeezed out, and subjected to the microscope, it is found to consist of innumerable minute globules of oil, surrounded by a transparent fluid.

The correctness of M. Bernard's observations has been called in question by Drs. Bence Jones, Lenz, Frerichs, Bidder, Schmidt, Lehmann, Donders, and Herbert. It is asserted that the bile and intestinal juice are even more active and efficient than the pancreatic juice, in the preparation of fatty matters for absorption. It is objected to Bernard's experiments, that he delayed his examination of the animals too long, and allowed the emulsion, formed with the bile, to pass down and be absorbed, before inspecting the viscera of the rabbits.[1]

Dr. Samuel Jackson, Professor of the Institutes of Medicine in the University of Pennsylvania, has recently examined this subject carefully, and repeated the experiments of Bernard, avoiding every source of error, and especially that of time, by causing oleaginous matters to enter the digestive apparatus, constantly, until the moment of observation. In every instance the results of his experiments confirmed the correctness of Bernard's conclusion, that the emulsion of fatty matters is produced by the action of the pancreatic juice. The doctor concludes his valuable paper by the following summary of the present state of our knowledge on this point:—

"1. Liquid fats are not miscible with the aqueous albumino-saline fluid—liquor

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[1] American Journal of the Medical Sciences, October, 1854, p. 307.

sanguinis—with which all the vascular tissues are saturated; it cannot enter their pores, and consequently cannot be absorbed.

"2. Liquid fats, when emulsified by albumen, are reduced to minute particles, each coated with albumen. In this state they are miscible with the liquor sanguinis, moistening the tissues, can enter their pores, and are then capable of absorption. This is the sole condition requisite for the absorption of fats.

"3. The white milk-like fluid, named chyle, is this emulsion of the fatty matters of the food, mixed with the ordinary lymph, always contained in the lymphatics of the alimentary canal, and other abdominal organs and mesentery. The molecular base of Gully is the microscopic appearance in the chyle, of the minute globules of fat coated with albumen.

"4. Albumen forms a perfect and persistent emulsion with oils. The pancreatic fluid is a saturated albuminous solution, and forms with oils an emulsion equally as perfect and permanent as that of albumen.

"5. The pancreatic juice is the only highly albuminous fluid in the alimentary canal, and can accomplish the formation of a perfect emulsion; and the opinion of M. Cl. Bernard, that this process is one of its functions, is, it appears to me, sustained.

"6. The observations of M. Cl. Bernard, that the formation of the emulsion of fats in rabbits is at and below the pancreatic duct, and not above it, is confirmed by the experiments reported in this communication. And further, that the experiments on rabbits are the most reliable, as being a true exemplification of the natural process, unattended with violence and torture to the animals, more or less disturbing in their effects.

"7. That M. Cl. Bernard's view of the decomposition of fats by the pancreatic juice is not proved, is opposed by the nature of the process, and by analogy with other emulsions; it is unnecessary to the accomplishment of the absorption of fats, and introduces other and complicated processes, that are unknown to exist, and are mere hypotheses."

Whilst engaged, last summer, in the investigation of the physical and chemical constitution of the fluids and the comparative anatomy and physiology of cold-blooded animals, it occurred to me that the pancreas of carnivorous animals should be larger than that of the frugivorous or granivorous animals, because it is much more incessantly exercised in the secretion of a fluid for the emulsifying of fats. Accordingly, I ascertained accurately the weights of the body and pancreas of every animal that came into my possession. Dividing the weight of the former by that of the latter, we obtain the weight of the pancreas in relation to that of the body, and the relative size of this organ in different animals is thus ascertained.

The weights of the animals were obtained with a pair of scales capable of turning to half a grain, and the weights of the organs with a delicate balance, capable of turning to $\frac{1}{1000}$th of a grain. The following table exhibits the most important results thus found.

Comparative Weights of the Pancreas of Carnivorous Fishes and Reptiles.

	Number of times the weight of its pancreas.
Weight of *Trygon sabina* (Female Stingray)	1071
" *Zygæna malleus* (Hammerhead Shark)	1045
" *Zygæna malleus* (Hammerhead Shark)	1563
" *Lepisosteus osseus* (Female Garfish)	193
" *Lepisosteus osseus* (Garfish)	272
" *Rana catesbæana* (Bullfrog)	1088
" *Heterodon niger* (Black Viper)	537
" *Psammophis flagelliformis* (Coachwhip Snake)	1353
" *Coluber guttatus* (Corn Snake)	1371
" *Coluber constrictor* (Black Snake)	472
" *Crotalus durissus* (Banded Rattlesnake)	965
" *Chelonia caretta* (Loggerhead Turtle)	518
" *Chelonura serpentina* (Snapping Turtle)	630
" *Emys terrapin* (Salt-water Terrapin)	994
" *Emys reticulata* (Chicken Terrapin)	763
" *Emys serrata* (Yellow-bellied Terrapin)	1067
" *Emys serrata* (Male Yellow-bellied Terrapin)	1200
" *Emys serrata* (Female Yellow-bellied Terrapin)	1343

Comparative Weights of the Pancreas of Frugivorous Chelonians.

	Number of times the weight of its pancreas.
Weight of *Testudo polyphemus* (Male Gopher)	3500
" *Testudo polyphemus* (Male Gopher)	3061

Comparative Weights of the Pancreas of Carnivorous Mammals.

	Number of times the weight of its pancreas.
Weight of *Procyon lotor* (Female Raccoon)	241
" *Procyon lotor* (Female Raccoon)	155
" *Procyon lotor* (Female Raccoon)	259
" *Procyon lotor* (fœtus of Raccoon)	583
" Common Cat	402
" Pointer Dog	337
" *Didelphis Virginianus* (Opossum)	192

Comparative Weights of the Pancreas of Frugivorous and Granivorous Mammals.

	Number of times the weight of its pancreas.
Weight of common sheep	1125
" *Sciúrus Carolinensis* (Gray Squirrel)	3026

By comparing these numbers, we arrive at the following conclusions:—

1. The pancreas of the Garfish (*Lepisosteus osseus*), a powerful, voracious and active fish, is much larger than that of more sluggish species. The Garfish consumes large numbers of small fishes, which it readily captures with its long and well armed jaws. The tissues and organs, especially the liver of fishes, contain much oil, and consequently a large gland is needed to afford a sufficient amount of the peculiar substance absolutely requisite for the preparation of the oleaginous

matter for absorption. We have previously stated that, in the pancreas of this remarkable fish we have conclusive proof of the function of this gland.

2. The pancreas of carnivorous fishes and reptiles is relatively much larger than that of frugivorous Chelonians. This difference in the relative size of this organ in these two classes, is evident at a glance. In the Ophidians it is a compact, ovoid gland, and in the carnivorous Chelonians it is a broad, lobulated, well developed, conspicuous gland; whilst in the frugivorous Gopher (*Testudo polyphemus*) it is a thin, delicate, obscure gland, composed of several slender lobes, subdivided into numerous lobules.

3. The pancreas of carnivorous Mammalia is much larger than that of the frugivorous or granivorous. The principal exception to this assertion appears in the Beaver, which is stated to have an unusually large pancreatic gland. A consideration, howver, of the character of the food of this animal will, we think, explain this anomaly. The stomach, and more especially the cæcum of the Beaver, is stated by observers to be filled up with fragments of bark and wood, which appear to constitute its chief aliment. The experiments of Mitscherlich have shown that alkaline solutions are capable of converting cellulose into starch, even more readily than concentrated acids. It is, therefore, highly probable that the great office of the alkaline pancreatic fluid in this animal is the preparation of cellulose for absorption, by converting it into starch.

4. The pancreas of carnivorous fishes and reptiles is larger than that of frugivorous and granivorous mammals, notwithstanding that the digestion of the former is much slower than that of the latter, and the amount of nutritive matters necessary to sustain the economy much less.

5. The pancreas of carnivorous mammals is larger than that of carnivorous cold-blooded animals; the digestive process is much more rapid, and correspondingly larger glands are needed to supply the secretions necessary for the proper preparation of the food for absorption.

The difference between the weights of the organ in these two classes of animals, does not correspond exactly with the disparity of their respective digestive processes, probably because the sluggish circulation and aeration of the blood, and the small amount of nervous force possessed by cold-blooded animals, require much larger organs to accomplish precisely the same results. As circulation and respiration are developed and perfected, and all the acts of life rendered correspondingly active, the more perfect and condensed become the organs and apparatus.

These results were shown, as far as simple dissection and inspection, upon other animals killed in swamps and woods, and at periods when it was impossible to ascertain their weights.

Our investigations upon birds have not been sufficiently extended to warrant general conclusions.

Whilst experimenting upon the effects of starvation and a change of diet upon the blood of carnivorous terrapins I found, as stated in a previous chapter, that the pancreas of many of those which had been deprived of food and drink for a length of time, and then placed in a tub of water and liberally supplied with vegetable food was diseased. Parts of the gland were of a black color and hard texture, and under the microscope contained cancer-like cells and crystals which resembled in

appearance those of the triple phosphate. It is probable that the gland, not being normally exercised, degenerated in structure.

In the first of a series of experiments which have not as yet been completed, I ascertained the correctness of M. Cl. Bernard's statement that fatty substances are not altered in the stomach or intestines of dogs if the pancreatic duct be tied.

The abdominal cavity of a remarkably large and voracious pointer dog, noted for his powerful digestive powers, was opened along the linea alba, and two fluidounces of lard oil secured in the stomach by ligatures above and below, and one fluidounce was injected and secured in the same manner in the intestines. The viscera were then carefully returned and the wound sewed up.

At the expiration of six hours the dog was killed, and the contents of the stomach and intestines had neither increased nor diminished, and were changed neither in physical or chemical properties, and the lymphatics of the mesentery did not appear to contain any milky emulsion. Under the microscope, the lard oil presented an appearance differing in no respect from that of ordinary oil.

Lard oil was inclosed separately in the stomach and intestines of a dog, and immersed for eighteen hours in the serum of this animal. At the end of this time neither endosmose of the serum nor exosmose of the oil had taken place. In the living dog the bloodvessels of the stomach and intestines retained their natural size and appearance. When saline solutions of high specific gravity were enclosed in a similar manner in the stomach and intestines of dogs and cats, the bloodvessels were congested with blood, and the internal surface of the mucous membrane presented a pinkish-purple color.

The following general conclusions have been drawn from this study of the comparative anatomy and physiology of the pancreas:—

1. In the Invertebrate Animals, this gland and the lymphatic system do not exist, because the character of the circulatory system, and the manner in which it receives the digested matters from the visceral cavity, are such, that the conditions requiring their presence are wanting.

2. In Fishes we may study the development of the pancreas, the permanent forms being but the transient conditions in the development of this gland in the higher animals.

3. The assertion of M. Cl. Bernard, that the chief office of the pancreas is to prepare fatty matters for absorption, is sustained by the following facts:—

a. In the Garfish (*Lepisosteus osseus*), the emulsion of the fatty matters takes place in the duct and cæca of the pancreas and their immediate vicinity, and nowhere else in the alimentary canal.

b. The pancreas of carnivorous animals is relatively much larger than that of frugivorous and granivorous ones. The amount of oil consumed by the former is much greater than that consumed by the latter. It may be inferred from these data, that the principal office of the pancreatic juice is the preparation of fats for absorption. This is farther sustained by the fact that the size of the pancreas amongst carnivorous animals is in a measure proportional to the amount of oleaginous matters consumed. The pancreas of the active, voracious Garfish, which destroys large numbers of small fish, is larger than that of the more sluggish fishes.

c. The pancreas of carnivorous Chelonians fed upon vegetable matters, degenerated in its structure.

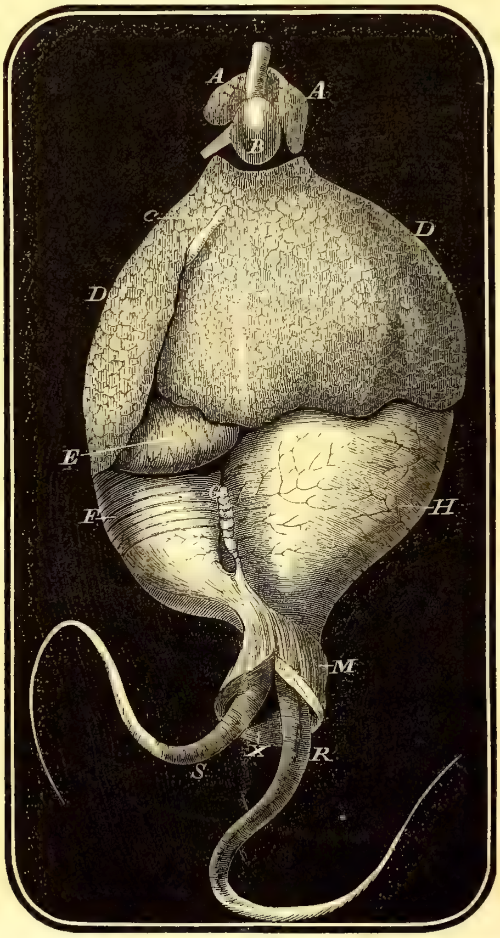
CHAPTER VII.

OBSERVATIONS UPON THE LIVER.

The form and appearance of the liver vary greatly in different animals. The shape and number of the lobes, and the general color, appear to follow no special law. The following observations, however, will show that its general form is often determined by that of the animal and its abdominal cavity.

The following figure represents the viscera of the Stingray (*Trygon sabina*).

Fig. 19.

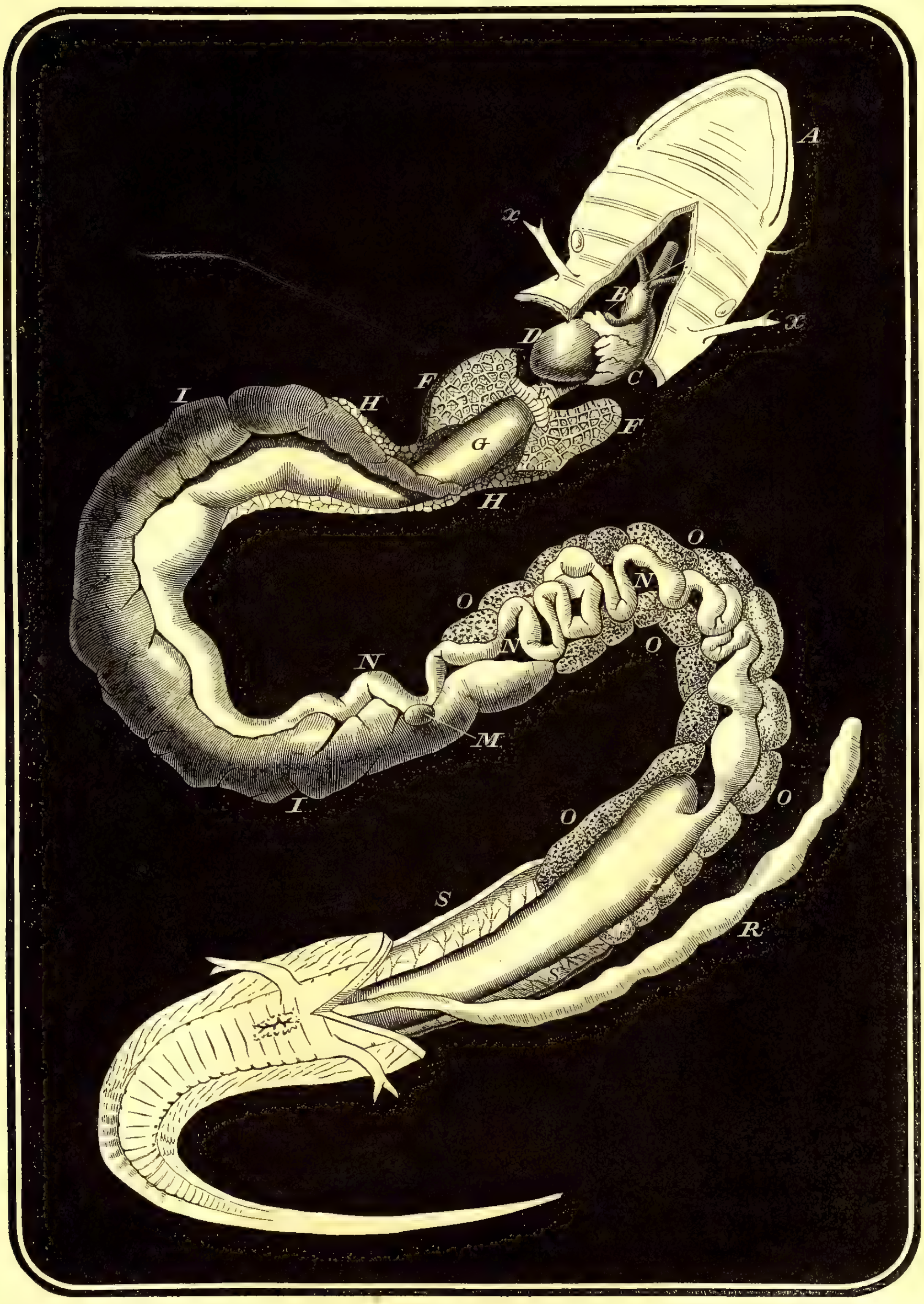


Viscera and impregnated uterus of the Stingray (*Trygon sabina*), reduced to one-half diameter. A, A. Auricle of the heart. B. Ventricle of the heart. D, D. Liver. C. Gall-bladder. E. Stomach. F. Intestine with spiral valve, which increases the extent of surface over which the digestive aliment is spread. The dark lines indicate the position and turns of the valve. H. Impregnated uterus. The tails of the Fœtal Stingrays are seen projecting out of the anus. G. Unimpregnated uterus and ovaries communicating with the cloaca. M. Cloaca. R, S. Tails of Fœtal Stingrays. X. Anus.

In many short, stout, and broad fishes, as the Stingray and Plaice, this organ is broad and thick.

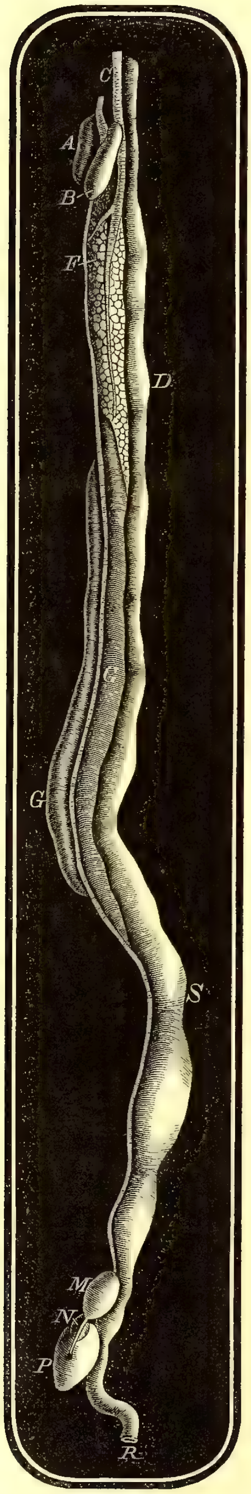
Fig. 20 represents the viscera of the Congo Snake (*Amphiuma means*).

Fig. 20



Viscera of the Congo Snake (*Amphiuma means*), reduced one-half diameter. A. Rough outline of head. B. Bulbus arteriosus, dividing into two principal branches. C. Auricle of heart. D. Ventricle of heart. E. Trachea, dividing and entering the lungs. F, F. Superior portions of the lungs slit open, showing their structure. G. Œsophagus and superior portion of stomach. H, H. Exterior surface of the lungs not slit open. I, I. Liver. M. Gall-bladder. N, N, N. Small intestines. O, O, O, O. Ovaries. P. Large intestine filled with claws of crustaceans and shells of molluscous animals, and particles of grass and leaves. R. Urinary bladder, remarkably long. Its contents are poured into the cloaca. S, S. Kidneys, flattened ribbon-like bodies. The lower portion of the figure is a rough sketch of the tail.

Fig. 21.



The general shape of the liver and viscera corresponds with that of the abdominal cavity and the fish.

In the Garfish, a long round fish having a correspondingly long and round abdominal cavity, the liver is elongated and resembles in appearance that of the doubtful reptiles and Ophidians. See Figure 11, representing the liver and viscera of the salt-water Garfish (*Lepisosteus osseus*).

In the Congo Snake (*Amphiuma means*) (Fig. 20), a long, slender, doubtful reptile, with an elongated narrow abdominal cavity, the general form of the liver is that of a long irregularly-shaped prism.

In the shorter and stouter Hellbender (*Menopoma Alleganensis*) and *Menobranchus maculatus,* this organ is correspondingly broad and short.

The liver of Batrachians generally consists of three lobes, and occupies the superior middle portion of the abdominal cavity.

This organ in serpents is narrow and much elongated, corresponding to the shape of the abdominal cavity, whilst in the round, thick-set Chelonians, it consists of two principal lobes extending across the abdominal cavity. These lobes in the Chelonia are united by a small isthmus, and resemble a pair of saddlebags.

Fig. 21 represents the viscera of a Corn-Snake (*Coluber guttatus*) This may be compared with Figs. 8, 9, 11, 19, and 20.

These differences corresponding to the general form of the animals, will be readily comprehended by comparing together the following figures:—

Fig. 19.	Viscera of	Stingray (*Trygon sabina*).
" 11.	"	Garfish (*Lepisosteus osseus*).
" 20.	"	Congo Snake (*Amphiuma means*).
" 21.	"	Corn Snake (*Coluber constrictor*).
" 8.	"	Snapping Turtle (*Chelonura serpentina*).
" 9.	"	Gopher (*Testudo polyphemus*).

The size of the liver also varies much, and, as far as my observations have extended, the difference can be accounted for neither by the habits, nor by the vital, chemical, or physical constitution of animals. The truth of this assertion will be readily verified by a reference to the following table of the relative weights of the livers of different animals, which were carefully ascertained upon delicate balances.

Viscera of Corn Snake (*Coluber constrictor*), reduced one-half diameter. C. Trachea or windpipe. A. Auricles of heart. B. Ventricle of heart. F. Superior vascular portion of the lung. D. Œsophagus. G, G. Liver. S. Stomach. M. Gall-bladder. N. Spleen. The hepatic duct is seen passing over the spleen and perforating the pancreas. P. Pancreas, compact ovoid gland attached to the small intestine. R. Divided end of small intestine.

Comparative Weights of the Liver of Animals.

	Number of times the weight of its liver.
FISHES.	
Weight of the body of *Trygon sabina* (Stingray) female	18
" " *Trygon sabina* (Stingray fœtus)	16
" " *Zygæna malleus* (Hammerhead Shark)	25
" " *Zygæna malleus* (Hammerhead Shark)	41
" " *Lepisosteus osseus* (Garfish)	75
" " *Lepisosteus osseus* (Garfish)	62
REPTILES.	
" " *Rana catesbiana* (Bullfrog)	55
" " *Heterodon niger* (Black Viper)	26
" " *Psammophis flagelliformis* (Coachwhip Snake)	71
" " *Coluber guttatus* (Corn Snake)	64
" " *Coluber constrictor* (Black Snake)	57
" " *Crotalus adamanteus* (Rattlesnake)	55
" " *Alligator Mississippiensis* (Alligator), male	73
" " *Chelonia caretta* (Loggerhead Turtle)	47
" " *Chelonura serpentina* (Snapping Turtle)	42
" " *Emys terrapin* (Saltwater Terrapin)	53
" " *Emys reticulata* (Chicken Terrapin)	18
" " *Emys serrata* (Yellow-bellied Terrapin)	36
" " *Emys serrata* (Yellow-bellied Terrapin)	25
" " *Emys serrata* (Yellow-bellied Terrapin)	48
" " *Testudo polyphemus* (Gopher)	50
" " *Testudo polyphemus* (Gopher)	45
BIRDS.	
" " Turtle Dove, male	77
" " *Meleagris gallopavo* (Wild Turkey)	70
" " *Meleagris gallopavo* (Wild Turkey)	67
" " *Picus erythrocephalus* (Redheaded Woodpecker)	33
" " Night Heron	22
" " *Tantalus loculator* (Wood Ibis)	68
" " *Tantalus loculator* (Wood Ibis)	64
" " *Syrnium nebulosum* (Barred Owl)	56
" " *Cathartes atratus* (Black Buzzard)	47
MAMMALS.	
" " *Didelphis Virginianus* (Opossum)	26
" " Common Sheep	61
" " *Sciurus Carolinensis* (Gray Squirrel)	43
" " *Sciurus capistratus* (Fox Squirrel)	48
" " *Cervus Virginianus* (Fœtus of Deer)	35
" " *Cervus Virginianus* (Fœtus of Deer)	42
" " *Mus rattus* (Rat just born)	39
" " *Mus rattus* (Rat just born)	36
" " *Mus rattus* (Rat half grown)	20
" " *Procyon lotor* (Raccoon), female	25
" " *Procyon lotor* (Raccoon), female	19
" " *Procyon lotor* (Raccoon), female	23
" " *Procyon lotor* (Raccoon, just born)	24
" " Pointer Dog, female	32
" " Common Cat, female	36

M. Cl. Bernard and other physiologists consider one essential function of the liver to be the elaboration of the blood. Chemical analyses have shown that the blood-corpuscles are more numerous in the blood after passing out of this organ than

when entering into it. It is, therefore, reasonable to believe that the blood-corpuscles have their origin in the liver. If the main offices of the liver be the elaboration of the albumen, and the formation of the blood-corpuscles, we might infer that it should be larger in warm than in cold-blooded animals, because in the former the blood is more abundant and much more rapidly formed and consumed in supplying the wastes of the tissues than in the latter.

Another function of the liver is the production of grape sugar. Physiologists of high reputation suppose that this is used in the production of animal temperature. If the supply of grape sugar corresponds to the temperature, the liver should be largest in warm-blooded animals.

These are the considerations which led me to investigate the relative size of this organ in different animals. But it must be stated, decidedly, that these views have not been sustained by my researches. A reference to the table shows us that the liver is smaller in Birds than in many Fishes, Reptiles, and Mammals, while the former have the highest temperature and the greatest number of blood-corpuscles.

Notwithstanding these results we need not abandon the preceding physiological doctrines, as no organ in the bodies of animals is so liable to alterations in its weight, unconnected with its secretory or excretory apparatus, as the liver. Fishes especially contain an extraordinary amount of oil. I have detected the presence of oil under the microscope, in the form of innumerable small globules in the livers of all animals, and even in the livers of cold-blooded animals which had been starved for sixty days, and warm-blooded animals which had been starved to death. In the cold-blooded animals, although every particle of fat had disappeared from their tissues, and the animals had died from starvation, still oil globules were found in considerable numbers in their livers. Again, the structure of the liver in cold-blooded animals, and fishes especially, is much softer and less compact than in the warm-blooded ones. These facts show that the weight of the liver is not a true exponent of that portion of the gland which is devoted to the elaboration and formation of the constituents of the blood.

The livers of all animals, cold or warm-blooded, always, as far as my observation has extended, yield grape sugar. I have detected its presence by various tests in the livers of numerous Fishes, Batrachians, Ophidians, Chelonians, Birds, and Mammals. I have found it in the livers of cold-blooded animals at all periods of starvation, and even after death from a deprivation of food and drink. In the liver, however, of a dog which was starved to death, I failed to discover any of it.

These facts show that, during starvation, grape sugar must be formed in the animal economy in part, from the nitrogenized elements.

One of the most prominent effects of starvation in all animals is the consumption of the fatty matters. Fat is found in considerable quantities in the livers of all animals, whether supplied with, or deprived of food and drink; and a universal accompaniment of this fat is grape sugar, a substance closely allied to it in chemical constitution. A relation, therefore, appears to exist between the consumption of fat in the animal economy and the production of grape sugar; but what this relation is, and whether grape sugar is formed from fat, has never been determined.

After its production in the liver, grape sugar passes into the circulation and disappears in the lungs as long as a normal respiration is maintained. I demonstrated by numerous careful[1] experiments upon cold-blooded animals the following facts:—

1. Grape sugar is never normally a constituent of the urine.

2. If the supply of oxygen be cut off from cold-blooded animals by placing them in carbonic acid or hydrogen gas, or by closing the trachea completely, grape sugar accumulates in the blood and is eliminated by the kidneys. The disappearance of this substance in the lungs depends, therefore, upon the introduction of oxygen.

3. In cold-blooded animals the function of the liver in producing sugar continued after the exclusion of the oxygen.

4. The appearance of grape sugar in the urine was accompanied in every instance by remarkable alterations in the forms and appearance of the blood-corpuscles under the microscope.

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[1] The excretions of the kidneys in cold-blooded animals, generally, are scanty. Chelonians are the best adapted for such experiments on account of their capacious bladders. They were prepared by being starved for a length of time, and then transferred to a tub of water and abundantly supplied with vegetable food (*Portulacca oleracea*). The excretions of the kidneys were thus rendered copious.

CHAPTER VIII.

OBSERVATIONS UPON THE SPLEEN.

THE spleen is absent from all invertebrate animals without exception. It is also wanting in the *Amphioxus*, the connecting links between Fishes and the higher forms of the Mollusca.

In the Cyclostomi and *Lepadogaster*, it is said to be of such small size as to be readily overlooked.

It varies much in size, form, and position, in different fishes. In the Stingray (*Trygon sabina*) it is large and oval (Figs. 12 and 13). In the Hammerhead Shark (*Zygœna malleus*) it is narrow and much elongated, as in the following figure:—

FIG. 22.

FIG. 23.

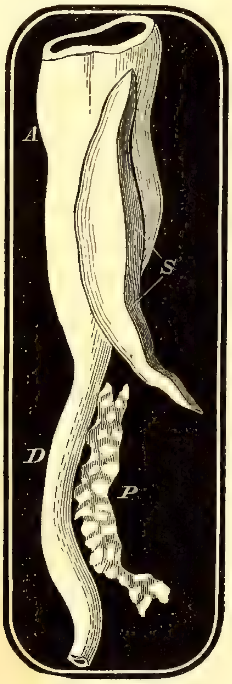


Fig. 22. Stomach, spleen, and pancreas of the Hammerhead Shark (*Zygæna malleus*) reduced one-half diameter. A. Superior portion of stomach. B. Stomach. C, C. Spleen. D, D, D. Small intestine. P, P, P. Pancreas.

Fig. 23. Stomach, spleen, and pancreas of Congo Snake (*Amphiuma means*) reduced one-half diameter. A. Stomach. S. Spleen. D. Small intestine. P. Pancreas.

In the Plaice (*Platessa oblonga*) it is small and oval. See Fig. 10.

The Garfish has frequently two large spleens situated in contact with the inferior surface of the pancreas.

In both the salt and fresh-water Garfishes, this organ is of large size, and often varies in its form in individuals belonging to the same species.

The form of the spleen varies much in the doubtful reptiles. It is elongated and ribbon-like in the Congo Snake (*Amphiuma means*, Fig. 23), and flatter, broader, shorter, and more oval in the Hellbender (*Menopoma Alleganensis*) and Proteus of the Lakes (*Menobranchus maculatus*). In these reptiles the spleen lies upon the left side. The following figures will illustrate these differences:—

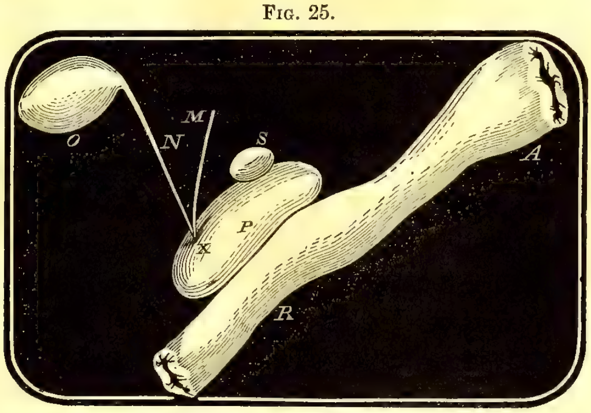
FIG. 24.

Stomach, spleen, and pancreas of the Hellbender (*Menopoma Alleganensis*) reduced one-half diameter. A. Stomach. S. Spleen. P. Pancreas. R. Small intestine.

The spleen of Batrachians is generally oval or kidney-shaped, and of small size, and occupies a position near the median line of the body.

The spleen of Ophidians is a small oval body, firmly attached to the superior and anterior surface of the pancreas, from which it is readily distinguished by its color. This is true of this organ in the Hognose Viper (*Heterodon platyrhinos*), Black Viper (*Heterodon niger*), Grass Snake (*Tropidonotus ordinatus*), Green Snake, (*Leptophis aestivus*), Coachwhip Snake (*Psammophis flagelliformis*), Pine Snake, (*Pituophis melanoleucus*), Indigo Snake (*Coluber couperi*), Chicken Snake (*Coluber quadrivittatus*), Corn Snake (*Coluber guttatus*, Fig. 25), Black Snake (*Coluber con-*

FIG. 25.

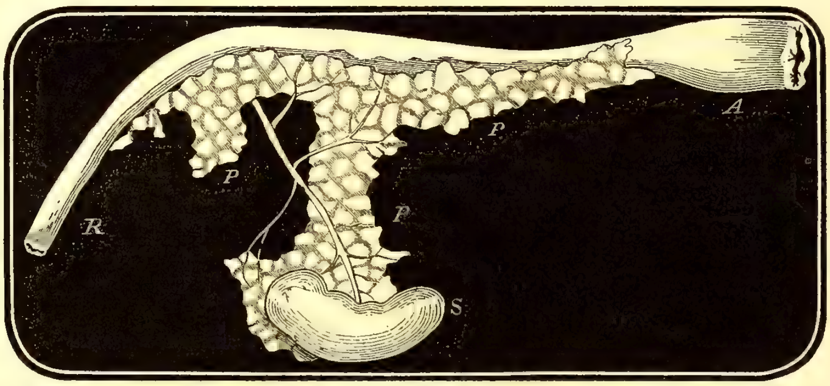


Spleen, pancreas, and gall-bladder of Corn Snake (*Coluber guttatus*), natural size. A. Inferior portion of stomach. R. Small intestine. P. Pancreas. S. Spleen. O. Gall-bladder. N. Cystic duct. M. Hepatic duct.

strictor), Water Mokeson (*Trigonocephalus piscivorus*), Copperhead (*Trigonocephalus contortrix*), Ground Rattlesnake (*Crotalophorus miliarius*), Banded Rattlesnake (*Crotalus durissus*), and Water Rattlesnake (*Crotalus adamanteus*). (*See* Figs. 21 and 25.)

In the Chelonians, the spleen varies much in size and appearance, even in individuals of the same species. In the Soft-shelled Turtle (*Trionyx ferox*), it is of large size, kidney-shaped, and lies a little to the left of the median line of the body, with its anterior concave border in contact with the inferior border of the pancreas. (*See* Fig. 26.)

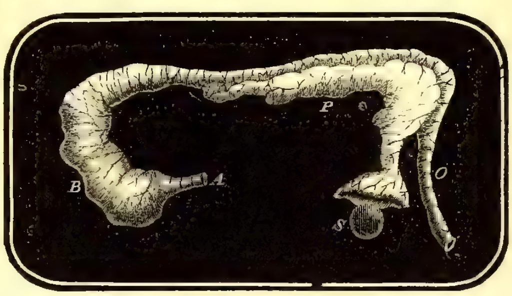
Fig. 26.



Spleen and pancreas of Soft-shelled Turtle (*Trionyx ferox*). A. Inferior portion of stomach. P, P, P. Pancreas. S. Spleen. R. Small intestine. (Reduced one-half diameter.)

In the Salt-water Terrapin (*Emys terrapin*), Chicken Terrapin (*Emys reticulata*), and Yellow-bellied Terrapin (*Emys serrata*), it is smaller and more oval in shape. (*See* Fig. 27.)

Fig. 27.



Spleen, pancreas, and stomach of Salt-water Terrapin (*Emys terrapin*), reduced one-half diameter. A. Inferior portion of œsophagus. B. Stomach. O. Small intestine. P. Pancreas. S. Spleen.

The spleen is of very small size in all birds, generally oval in form, and situated near the anterior extremity of the pancreas.

In the Mammalia this organ is larger, and presents manifold diversities of form. In all animals it may be distinguished, almost immediately, by its color alone.

The researches of Professors Ecker and Kölliker, M. Beclard, Dr. Gray, and other physiologists and chemists, have shown that the blood-corpuscles undergo important changes in the spleen.

If the function of the spleen be that of the formation and destruction of the blood-corpuscles, it is reasonable to suppose that it should be much larger in warm than in cold-blooded animals, because the number of the blood-corpuscles is greater,

and all the changes of the elements of the fluids and solids much more rapid in the former than in the latter.

To determine this point, I ascertained accurately the weights of the bodies and spleens of cold and warm-blooded animals, contained in the following tables. The first represents the absolute weights of the bodies and spleens, and the last the relative weights of the spleen.

Weights of the Bodies and Spleens of Animals.

Name of animal.	Weight of the body.	Weight of the spleen.
FISHES.	Grains.	Grains.
Trygon sabina (Stingray), female	16,400	56
Trygon sabina (Stingray), fœtus	610	$\frac{6}{10}$
Zygæna malleus (Hammerhead Shark)	54,350	89
Zygæna malleus (Hammerhead Shark)	6,568	14
Lepisosteus osseus (Garfish)	22,303	38
Lepisosteus osseus (Garfish)	52,110	87
REPTILES.		
Rana catesbiana (Bullfrog)	9,800	$4\frac{3}{10}$
Heterodon niger (Black Viper)	4,620	$\frac{18}{100}$
Psammophis flagelliformis (Coachwhip Snake)	5,141	$\frac{8}{10}$
Coluber guttatus (Corn Snake)	9,600	1
Coluber constrictor (Black Snake)	5,100	$\frac{7}{10}$
Crotalus adamanteus (Water Rattlesnake)	6,180	$\frac{4}{10}$
Alligator Mississippiensis (Alligator), male	76,507	58
Alligator Mississippiensis (Alligator), female	211,940	266
Chelonia caretta (Loggerhead Turtle)	36,985	$16\frac{8}{10}$
Chelonura serpentina (Snapping Turtle)	16,235	$20\frac{3}{10}$
Emys terrapin (Salt-water Terrapin)	11,937	$1\frac{5}{10}$
Emys reticulata (Chicken Terrapin)	8,400	$8\frac{7}{10}$
Emys serrata (Yellow-bellied Terrapin)	27,172	$16\frac{8}{10}$
Emys serrata (Yellow-bellied Terrapin)	14,400	$12\frac{8}{10}$
Emys serrata (Yellow-bellied Terrapin)	23,100	$20\frac{3}{10}$
Testudo polyphemus (Gopher)	45,500	18
Testudo polyphemus (Gopher)	18,368	$5\frac{1}{10}$
BIRDS.		
Meleagris gallopavo (Wild Turkey), female	36,312	$23\frac{6}{10}$
Meleagris gallopavo (Wild Turkey), female	28,875	11
Picus erythrocephalus (Red-headed Woodpecker)	1,060	$\frac{2}{10}$
Tantalus loculator (Wood Ibis)	39,375	11
Tantalus loculator (Wood Ibis)	37,625	$18\frac{9}{10}$
Syrnium nebulosum (Barred Owl)	10,580	$7\frac{2}{10}$
Cathartes atratus (Black Buzzard)	31,937	26
MAMMALS.		
Didelphis Virginianus (Opossum)	18,812	45
Common Sheep	385,000	652
Sciurus Carolinensis (Gray Squirrel)	6,960	$10\frac{2}{10}$
Sciurus capistratus (Fox Squirrel)	14,710	16
Cervus Virginianus (Fœtus of Deer)	26,935	95
Cervus Virginianus (Fœtus of Deer)	26,953	77
Mus rattus (Rat just born)	$99\frac{7}{10}$	$\frac{2}{10}$
Mus rattus (Rat just born)	$84\frac{2}{10}$	$\frac{1}{6}$
Mus rattus (Rat half grown)	1,063	$2\frac{1}{10}$
Lepus sylvaticus (Common Rabbit)	20,928	14
Procyon lotor (Raccoon), female	47,787	139
Procyon lotor (Raccoon), female	54,735	391
Procyon lotor (Raccoon), female	59,110	203
Procyon lotor (Raccoon just born)	1,750	$11\frac{2}{10}$
Pointer Dog (male)	247,126	428
Common Cat (female)	35,000	67

Comparative Weights of the Spleens of Animals.

	Number of times the weight of its spleen.
FISHES.	
Weight of the body of *Trygon sabina* (Stingray), female	292
" " *Trygon sabina* (Stingray fœtus)	1,016
" " *Zygæna malleus* (Hammerhead Shark)	601
" " *Zygæna malleus* (Hammerhead Shark)	443
" " *Lepisosteus osseus* (Garfish)	587
" " *Lepisosteus osseus* (Garfish)	599
REPTILES.	
" " *Rana catesbiana* (Bullfrog)	2,279
" " *Heterodon niger* (Black Viper)	25,666
" " *Psammophis flagelliformis* (Coachwhip Snake)	6,426
" " *Coluber guttatus* (Corn Snake)	9,600
" " *Coluber constrictor* (Black Snake)	7,285
" " *Crotalus adamanteus* (Rattlesnake)	15,450
" " *Alligator Mississippiensis* (Alligator), male	1,319
" " *Alligator Mississippiensis* (Alligator), female	798
" " *Chelonia caretta* (Loggerhead Turtle)	2,201
" " *Chelonura serpentina* (Snapping Turtle)	800
" " *Emys terrapin* (Salt-water Terrapin)	7,958
" " *Emys reticulata* (Chicken Terrapin)	965
" " *Emys serrata* (Yellow-bellied Terrapin)	1,618
" " *Emys serrata* (Yellow-bellied Terrapin)	1,125
" " *Emys serrata* (Yellow-bellied Terrapin)	1,138
" " *Testudo polyphemus* (Gopher)	2,527
" " *Testudo polyphemus* (Gopher)	3,600
BIRDS.	
" " *Meleagris gallopavo* (Wild Turkey), female	1,538
" " *Meleagris gallopavo* (Wild Turkey), female	2,625
" " *Picus erythrocephalus* (Red-headed Woodpecker)	2,120
" " *Tantalus loculator* (Wood Ibis)	3,579
" " *Tantalus loculator* (Wood Ibis)	2,044
" " *Syrnium nebulosum* (Barred Owl)	1,470
" " *Cathartes atratus* (Black Buzzard)	1,228
MAMMALS.	
" " *Didelphis Virginianus* (Opossum)	418
" " Common Sheep	590
" " *Sciurus Carolinensis* (Gray Squirrel)	682
" " *Sciurus capistratus* (Fox Squirrel)	919
" " *Cervus Virginianus* (Fœtus of Deer)	283
" " *Cervus Virginianus* (Fœtus of Deer)	350
" " *Mus rattus* (Rat just born)	498
" " *Mus rattus* (Rat just born)	505
" " *Mus rattus* (Rat half grown)	506
" " *Lepus sylvaticus* (Common Rabbit)	1,494
" " *Procyon lotor* (Raccoon), female	343
" " *Procyon lotor* (Raccoon), female	292
" " *Procyon lotor* (Raccoon), female	391
" " *Procyon lotor* (Raccoon just born)	156
" " Pointer Dog (male)	577
" " Common Cat (female)	522

These tables show that the spleen is smallest in Birds and Ophidians, and largest in Fishes and Mammals. The temperature of Birds is high, their blood-corpuscles numerous, their life-actions vigorous, and the physical and chemical changes of the elements of their fluids and solids correspondingly rapid. In Fishes, circulation

and respiration are sluggish, the blood-corpuscles few in numbers, the temperature low, the metamorphosis of the elements of their structure slow, and the intellect and all the life actions correspondingly feeble.

If the function of the spleen be the construction, destruction, and elaboration of some of the important elements of the blood, why is it so small and insignificant in birds, and of such great relative magnitude in many cold-blooded animals? Is it possible that an organ, which, in many Ophidians, Chelonians, and Birds, weighs only a few grains or a small fraction of a grain, can exert any important influence upon the physical properties and chemical constitution of the blood? Do not these facts show conclusively that we do not understand the functions of the spleen?

Mr. Gray[1] supposes that one office of the Malpighian corpuscles is to store up nutritive matter when there is a surplus of alimentary materials; to be restored again to the blood when there is a deficiency of these elements. It is, however, difficult to conceive, how nutritive matter of any importance could be stored up in the Malpighian corpuscles of organs, weighing a few grains or only fractions of a grain. The amount accumulated in such organs would be microscopic in its character, and not much more than the hundredth part of a grain.

Even in warm-blooded animals the amount of albuminous compounds contained in the Malpighian corpuscles of the spleen is insignificant, and unworthy of notice when compared with that contained in the circulatory apparatus, the capacious reservoir of the nutritive materials. The circulatory apparatus of an adult man contains, according to the most recent and reliable calculations, about twenty-two pounds of blood, whilst the Malpighian corpuscles of the spleen are capable of containing only a few grains.

Would nature construct an organ, an important office of which would be to store up a few grains of nutritive matter, whilst the circulatory system contains more than ten thousand times the amount?

Mr. Gray instituted a valuable series of researches upon the effects of diet upon the spleen of Cats, Rabbits, and Rats, and found that this organ increases during active nutrition. As far as my observations have extended this phenomenon does not occur in cold-blooded animals.

The spleens of Salt-water Terrapins (*Emys terrapin*) and of Yellow-bellied Terrapins (*Emys serrata*), which had been starved and deprived of water for a great length of time, and then transferred to a tub of water and abundantly supplied with vegetable food, did not exhibit any increase in weight. I have also observed, in numerous instances, that the spleen of cold-blooded animals does not act as a diverticulum for any surplus water or nutritive materials in the circulatory apparatus.

The spleens of many carnivorous Chelonians, whose circulatory apparatus was so filled with blood consequent upon a change of diet, that aqueous albumino-saline effusions took place into the cellular tissue, and all the cavities, presented no increase in size or weight.

The spleens of Ophidians, which are voracious and swallow large masses of flesh,

[1] The Structure and Use of the Spleen, by Henry Gray, F. R. S. London, 1854.

were not enlarged, notwithstanding the large amount of nutritive substances which were received into their circulatory apparatus.

That the spleen is an organ of subordinate importance in the animal economy will be shown by the following facts:—

It is absent from all invertebrate animals without exception. It is also absent from the *Amphioxus*, the connecting link between fishes and the higher forms of the mollusca.

In the *Amphioxus* and Invertebrate animals the blood-corpuscles are always colorless. The occurrence of the spleen is accompanied by a change in the color of the blood.

Has the spleen anything to do with the production of the red blood-corpuscles of vertebrate animals? The blood of the invertebrata, with its corpuscles, exists before the formation of any special organs. The same fact is noticed in the development of the fœtus of warm-blooded animals.

A vascular system circulating a fluid containing colored blood-corpuscles exists before the formation of any special organs, and hence it is probable that the spleen has little to do with the formation of the corpuscles and the production of their red color. This conclusion is farther sustained by the fact that the amputation of the spleen of Dogs and other animals is not followed by any alteration in the amount or character of the blood and its constituents, and they enjoy very good health, and there is no sensible difference between them and those that have not undergone the operation. From these investigations we may draw the following conclusions:—

1. The spleen of Birds and many Reptiles is too small to exert an important influence in the animal economy.

2. Its size corresponds in no manner with the number of blood-corpuscles, or the rapidity of the composition and decomposition of the organic and inorganic elements of the fluids and solids of animals.

3. Of the real office of the spleen in the animal economy we are still ignorant.

4. The function of the spleen is not indispensable to the maintenance of life.

CHAPTER IX.

OBSERVATIONS UPON THE KIDNEY.

In the present chapter we do not propose to treat of the comparative anatomy and physiology of this organ in general, but simply to record a few observations which we consider of importance.[1]

June 27. The kidneys of a small Chicken Snake (*Coluber guttatus*), about two and a half feet in length, and those of a large Coachwhip Snake, were carefully amputated. The bloodvessels were secured and the wounds closed. The Chicken Snake was placed in a glass jar and remained in confinement for three and a half days, when it pushed off the top and made its escape, although this was held down by a pound weight. The serpent, therefore, must have been strong and active at the time of its escape.

The Coachwhip Snake died at the end of three and a half days. Its viscera presented remarkable appearances. The lung contained considerable quantities of coagulated blood effused into the air-cells. The blood contained numerous minute white particles. The exterior serous covering of the lungs, the internal surface of its air-cells and coats of its bloodvessels, the serous covering of the intestines, abdominal cavity, and surface of the liver, were covered with small white granules, appearing as if fine white sand had been sprinkled over them. The deposit was in all cases most abundant in the course of the bloodvessels. When the internal structure of the liver was cut or torn it was found to be completely impregnated with these small white masses which could be readily squeezed out, and appeared to occupy principally the neighborhood of the bloodvessels.

At the lower portion of the abdominal cavity, where the kidneys had been amputated, the blood effused, and the peritoneum, with the internal surface of the epidermis, where it had been removed from the muscles, were completely covered with large numbers of these white granules having the appearance to the sight and touch of grains of sand. This increased deposition in the region of the wound was without doubt due to the more active determination of blood towards this part. The intestines were found to contain the same deposit, none of it, however, was found in the humors of the eye and muscular tissue.

These granular masses from all parts of the abdominal cavity, and its viscera and peritoneal coverings, and from the exterior and interior of the lungs were carefully

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[1] See Observations by the Author upon the Kidney and its Excretions in Different Animals, American Journal of Medical Sciences, April, 1855.

examined microscopically and chemically. In every instance under the microscope they were found to be composed of small granules and delicate acicular crystals.

All the characteristic chemical tests gave unequivocal evidence that these granules were composed of uric acid and ammonia. A careful microscopical examination also showed that they were the urate of ammonia, which is the most abundant constituent of the urine of serpents.

From the results of this experiment we may draw the following conclusions:—

1. The kidneys are excreting and not secreting organs. The circulatory apparatus not only carries nutriment to the different organs and tissues, but also removes from them the products of their disintegration and metamorphosis of no further use in the animal economy.

The amount and character of an excretion depends entirely upon the amount and character of the excrementitious materials existing in the blood.

A secretion does not exist in the blood. We do not find the gastric juice or the salivary fluid existing in the blood before they are elaborated by special organs.

2. When the kidneys are amputated, other membranes and organs assume their office of depurating the blood. In like manner, if the function of the skin be checked it will be assumed by the kidneys. The act, then, of separating certain materials from the blood can be transferred from one excretory organ to another. This, however, is not true of secretions. Each secretion must have a special set of cells, which alone can produce the peculiar material.

We never find one organ elaborating the secretion of another distinct organ. This is a general law. The salivary gland never secretes gastric juice, nor the mammillary gland, bile. The stomach of a Rattlesnake never secretes the deadly fluid of its poison gland. Thus, in two essential respects, a secretion differs from an excretion.

3. It is probable that in the lower animals which are without kidneys, the office of the latter is carried on by the mucous membrane of the stomach and intestinal canal.

We will next consider the relative size of the kidneys in the four great classes of vertebrate animals.

Comparative Weights of the Kidneys of Animals.

	Number of times the weight of its kidneys.
FISHES.	
Weight of the body of *Trygon sabina* (Stingray), female	188
" " *Trygon sabina* (Stingray) fœtus	93
" " *Zygæna malleus* (Hammerhead Shark)	346
" " *Zygæna malleus* (Hammerhead Shark)	335
REPTILES.	
" " *Rana catesbiana* (Bullfrog)	515
" " *Heterodon niger* (Black Viper)	177
" " *Psammophis flagelliformis* (Coachwhip Snake)	88
" " *Coluber guttatus* (Corn Snake)	152
" " *Coluber constrictor* (Black Snake)	76
" " *Crotalus adamanteus* (Rattlesnake)	131
" " *Alligator Mississippiensis* (Alligator), male	135
" " *Alligator Mississippiensis* (Alligator), female	145
" " *Chelonia caretta* (Loggerhead Turtle)	368
" " *Chelonura serpentina* (Snapping Turtle)	249
" " *Emys terrapin* (Salt-water Terrapin)	775
" " *Emys reticulata* (Chicken Terrapin)	280
" " *Emys serrata* (Yellow-bellied Terrapin)	409
" " *Emys serrata* (Yellow-bellied Terrapin)	416
" " *Emys serrata* (Yellow-bellied Terrapin)	495
" " *Testudo polyphemus* (Gopher)	322
" " *Testudo polyphemus* (Gopher)	360
BIRDS.	
" " *Ectopistes Carolinensis* (Turtle Dove), female	182
" " *Ectopistes Carolinensis* (Turtle Dove), male	237
" " *Ortyx Virginiana* (Quail)	125
" " *Meleagris gallopavo* (Wild Turkey)	204
" " *Meleagris gallopavo* (Wild Turkey)	206
" " *Picus erythrocephalus* (Redheaded Woodpecker)	81
" " *Ardea nycticorax* (Night Heron)	97
" " *Tantalus loculator* (Wood Ibis)	168
" " *Tantalus loculator* (Wood Ibis)	171
" " *Buteo borealis* (Hen Hawk)	141
" " *Syrnium nebulosum* (Barred Owl)	176
" " *Cathartes atratus* (Black Turkey-Buzzard)	132
" " *Ardea candidissima* (Snowy Heron)	86
MAMMALS.	
" " *Didelphis Virginianus* (Opossum)	131
" " Common Sheep	350
" " *Sciurus Carolinensis* (Gray Squirrel)	175
" " *Sciurus capistratus* (Fox Squirrel)	147
" " *Lepus sylvaticus* (Common Rabbit)	186
" " *Mus rattus* (Young Rat), just born	90
" " *Mus rattus* (Young Rat), just born	105
" " *Mus rattus* (Rat), half grown	92
" " *Procyon lotor* (Raccoon), female	66
" " *Procyon lotor* (Raccoon), female	57
" " *Procyon lotor* (Raccoon), female	61
" " *Procyon lotor* (Raccoon), just born	68
" " Pointer Dog	178
" " Common Cat	142

The following conclusions may be derived from this table:—

1. The kidneys of Ophidians and Saurians are much larger relatively than those of the Chelonians. This difference will be readily understood by a comparison of the habits and vital and physical constitution of these two classes.

Serpents take their food in large quantities, often swallowing animals heavier and larger than themselves. All this animal matter is capable of digestion and absorption into the blood, a large portion of which is superfluous, and must be eliminated by the kidneys. The carnivorous Chelonians, on the other hand, are much more moderate, and slow in the indulgence of their appetites. This arises from necessity rather than choice. Their motions are so slow, their disposition to shut themselves up in their shells so great, and their mouth so small, that their appetites are not indulged to such an extent as to burden the kidneys, and call for an increase in their size.

The rapidity of the wastes of the tissues, as we have previously shown, is proportional to the rapidity of the vital actions. Hence, the kidneys will have more to do in active animals than in the sluggish. Many serpents, as the black snake and coachwhip snake, are remarkably active, and all Ophidians are more energetic than the proverbially sluggish Chelonians. Here we have another reason why the kidneys should be larger in the former than in the latter. Those Chelonians which inhabit the water should have smaller kidneys than those Ophidians which inhabit the land, because the function of the skin is much more active in the former than in the latter. The skin of most serpents is completely covered by horny scales, and its power of removing fluids, and, the products of the metamorphoses of the tissues must be very feeble.

2. As far as my observations have extended, it may be asserted, as a general rule, that the kidneys are relatively larger in the carnivorous than in the frugivorous or granivorous birds. In the carnivorous birds, the intestinal canal is much shorter than those living upon a vegetable or mixed diet. Their food is capable of more rapid digestion, and introduction into the circulation, and as a necessary consequence, the organ which regulates, in a great measure, the amount of the solid and fluid materials of the blood, and eliminates all waste and useless matters, must be correspondingly large. Carnivorous birds also appear to be more active and energetic than the frugivorous or granivorous.

Another reason is found in the chemical constitution of the food. This, however, will be considered when we come to study the same law in the Mammalia.

3. The kidneys of the carnivorous Mammalia are relatively larger than those of the graminivorous or frugivorous ones. This may be stated to be generally true, as far as our observations have extended.

If the character of the food, the structure and size of the digestive apparatus, and the habits of the two classes of animals, be attentively considered, we will understand at once why this relative difference should exist in organs fulfilling the same office in both.

The food of the Carnivora, as the name implies, consists of flesh and blood, which is capable of ready digestion and absorption, and rapidly supplies the wants of the animal economy. The intestinal canal is in all cases short when compared with that of the Mammalia, which feed on vegetable substances. Carnivorous animals have voracious, and, in most cases, almost insatiable appetites. They gorge themselves with food, which is capable of entering the circulation with little or no alteration, and rapidly supplies the wants of the economy. There must be some organ to act as a safety-valve, and remove quickly the large unnecessary

quantities of nutriment, which are so often received into the circulatory system. To accomplish this effectually, there must be correspondingly large organs.

In the Herbivora and Granivora, on the other hand, the intestinal canal is long; in the case of the sheep, it is more than twenty times the length of the body. In this class of animals, the food requires minute subdivision, and the materials which they contain must go through many metamorphoses before they are ready to supply the wastes and wants of the system. Consequently, their introduction into the circulation is gradual; the elimination of the products of the disintegrations of the tissues, whose place they supply, must be correspondingly slow, and a much smaller sized organ will perform the same office in them than in the Carnivora.

Another important cause of this difference between the relative sizes of the kidneys of these classes of animals is to be found in the chemical constitution of the food.

The food of the Carnivora contains much nitrogen, and in the processes of its compositions and decompositions, for the production and maintenance of animal heat, is not completely consumed, and the resulting compounds, as uric acid, and urea, and ammonia, are eliminated principally by the kidneys. On the other hand, almost all the food of frugivorous and granivorous animals is capable of being ultimately resolved into water and carbonic acid gas, or of being converted into fat. The amount of nitrogenized elements to be eliminated by the kidneys is on this account greater in the former than in the latter.

The same law applies to the kidneys of cold-blooded animals. It is not, however, so evident at first sight.

The kidneys of Ophidians and Saurians, carnivorous reptiles, are much larger than those of the herbivorous Gopher (*Testudo polyphemus*); but the kidneys of carnivorous Chelonians are far smaller than those of the Gopher. How are we to explain this apparent anomaly? A consideration of the peculiar habits and constitution of these animals will answer the question.

The Gopher lives in a barren and sandy country, and to prevent evaporation from the surface, it is covered with horn at all points where the skin is exposed. The function of the skin is consequently little or nothing, and the kidneys must perform the labor. The carnivorous Chelonians, as the Salt-water Terrapin (*Emys Terrapin*), and Yellow-bellied Terrapin (*Emys serrata*), have a naked skin, and live in the water. The function of the skin in all those reptiles living in the water is far more active than that of those living out of it. That evaporation takes place rapidly through the skin of these Chelonians was conclusively shown by our experiments upon the effects of thirst and starvation upon their blood. These animals also do not consume as much food as the Gopher.

It is evident, from these reasons, that the small size of the kidneys of carnivorous terrapins is connected with their peculiar organization and mode of living; and they cannot be fairly compared with an animal differing totally from them in its physical and vital endowments, and mode of life. The Gopher should be compared with the carnivorous Ophidians and Saurians, because they all live upon the land, and their tegumentary systems are similar. A reference to the tables shows that the kidneys of the former are far smaller than those of the latter, and the truth of the generalization announced is sustained.

CHAPTER X.

URINE OF COLD-BLOODED ANIMALS.

I HAVE always found it very difficult to obtain specimens of the urine of Fishes, for examination. Their bladders are almost always empty. I am enabled, however, to furnish the following qualitative analysis of the urine of the Bass-fish or Red Fish (*Corvina ocellata*):—

Uric acid.	Phosphate of magnesia.
Oxalate of lime.	" of soda.
Phosphate of lime.	Chloride of sodium.
" of ammonia.	

When the urine was spread upon a glass slide, and allowed slowly to evaporate, under a magnifying power of 210 diameters, there appeared lozenge-shaped and hexagonal crystals of uric acid, dumb-bell and octohedral crystals of oxalate of lime, and prismatic crystals of triple phosphate.

The urine of Reptiles resembles that of Birds, not only in appearance, but also in chemical constitution—being only a little more solid when first discharged. Here we have the urine of two wholly dissimilar classes, alike in all respects.

Birds have a high temperature—in many cases 10° above that of Mammals. Their blood circulates with rapidity, and receives an abundant supply of oxygen. They are also very active in their habits.

The temperature of Reptiles is not constant; it varies with that of the surrounding medium. Respiration is imperfect—their lungs being, in most cases, simple sacs—around the walls of which ramify the bloodvessels. Their circulation is sluggish and imperfect, and their habits indolent and inactive. Would any one suppose, *à priori*, that the secretions of these two classes would be similar? If the explanation be true, that the production of urate of ammonia, in serpents, is due to their imperfect respiration and consequent incomplete oxygenation of the blood and tissues, why should we have the same state of things existing in birds, which have oxygen supplied in large quantities, not only by their lungs but also throughout the tissues, by means of their porous bones? It is, however, useless to speculate upon this subject, in the present state of our knowledge.

The following is a qualitative analysis of the urine of the Coachwhip Snake (*Psammophis flagelliformis*), which I made during the month of July.

When the urine was allowed to stand for a short time, it formed a hard, white mass, which might have been readily mistaken for so much chalk. Under a magnifying power of 210 diameters, it was seen to consist of a conglomeration of innu-

merable globules of the urate of ammonia, resembling, in all respects, the solid portion of the urine of birds. Epithelial cells and fibrinous casts of the urinary tubes, were also found.

The following are the results of the microscopical and chemical examination of the urine of this snake:—

Urate of ammonia, in great abundance.	Phosphate of soda.
Phosphate of lime.	Chloride of sodium.
" of ammonia.	Epithelial cells.
" of magnesia.	Fibrinous casts of urinary tubes.

We were unable to detect the presence of urea. We have, however, found this substance in small amount in the urine of other serpents.

The urine of the Black Viper (*Heterodon niger*), Hognose Viper (*Heterodon platyrhinos*), Indigo Snake (*Coluber couperi*), Corn Snake (*Coluber guttatus*), Chicken Snake (*Coluber quadrivittatus*), Rattlesnake (*Crotalus adamanteus*), and others yielded similar results upon a qualitative examination.

In the kidneys of the Indigo Snake (*Coluber couperi*), several pyriform calculi were found imbedded in their substances, extending from their anterior surfaces to the uterus. These calculi were found to consist, in large measure, of the oxalate of lime. Other substances were also present—as urate of ammonia and the phosphates of lime, ammonia, and magnesia.

The amount of urine excreted by the kidneys of Ophidians, during starvation, is exceedingly small. I have kept them, without food or drink, for several weeks, and the amount excreted during this time, often did not amount to more than 20 or 50 grains.

A male Alligator (*Alligator Mississippiensis*), which weighed 76,507 grains, was starved and deprived of water for eighteen days, and during that time it discharged its urine but once, in quantity about two fluidounces. This consisted, as in Ophidians and Birds, of a fluid and a solid, chalk-like portion, composed of minute globules of the urate of ammonia.

We shall next consider the urine of Chelonians. In these animals the bladder is large, and the urine resembles, in many respects, that of the Mammalia. The following table represents the specific gravities of the urine in its normal condition, and during starvation and a change of diet:—

Name of animal.	Specific gravities.	
Snapping Turtle (*Chelonura serpentina*)	1005.7	
Salt-water Terrapin (*Emys terrapin*)	1009.	
Emys terrapin, deprived of food and drink 40 days	1015.	
Emys serrata " " " 17 "	1011.	
" " " " 26 "	1033.5	
" " " " 29 "	1020.	
" " " " 31 "	1017.5	
" " " " 38 "	1017.6	
" " " " 49 "	1019.4	
Emys serrata, deprived of food and drink 28 days, and then transferred to a tub of water, and abundantly supplied with vegetable food (*Portulacca oleracea*)	999.26	81° F.
Emys serrata, deprived of food and drink 28 days, and then abundantly supplied with water and vegetable food	999.9	90° F.
Emys serrata, deprived of food and drink for 28 days, and then placed in a tub of water, and supplied with vegetable food	1004.	
Emys terrapin, deprived of food and drink 21 days, and then placed in fresh water, and supplied with vegetable food (*Portulacca oleracea*) .	1002.	
Gopher (*Testudo polyphemus*). The urine consists of two portions: 1. Fluid. 2. Semi-solid. . . . . Sp. gr. of fluid	1004.	
Sp. gr. of semi-solid	1095.5	
Gopher (*Testudo polyphemus*), deprived of food and drink 30 days. Sp. gr. of fluid portion of urine	1008.9	

This table shows that the specific gravity of the urine of Chelonians was increased, during starvation and thirst, and also, that when carnivorous Chelonians were fed upon purely vegetable diet, the specific gravity of the urine was greatly diminished.

From numerous examinations, which I made last summer, the following are selected as affording the best view of the physical and chemical properties of the urine.

Urine of a Yellow-bellied Terrapin (*Emys serrata*), which had been deprived of food and drink for 29 days. June 20.

Weight of terrapin, May 25th	30,132 grains.
" " June 19th	22,760 "
" lost in twenty-six days	7,372 "

Loss of weight each hour, $10\frac{5}{10}$ grains = $\frac{1}{2870}$th the original weight of the body. The bladder had not been emptied during its confinement, and contained four fluid-ounces of urine. Sp. gr. 1020. The urine was of a transparent yellow color, and contained white and yellow chalk-like masses, which, under the microscope, were found to consist of numerous minute globules of the urate of ammonia, and hexagonal and lozenge-shaped crystals of uric acid. The presence of ammonia and uric acid was determined by all the characteristic tests. The transparent portion of the urine was ropy, resembling mucus. When treated with *aqua ammoniæ*, a copious precipitate of triple phosphate was thrown down.

1000 parts of the urine contained—

Water	947.19
Solid constituents	52.81

A microscopical and chemical examination, revealed the following ingredients:—

Uric acid, in lozenge-shaped and hexagonal crystals.
Urate of ammonia, in minute globules.
Triple phosphate, prismatic and stellate crystals.
Phosphate of lime.
Phosphate of ammonia.
" of magnesia.
Carbonate of lime in stellate crystals.
Albumen in small quantity.
Mucus.

If urea was present, it must have been in very small quantities, for nitric acid and the microscope failed to reveal its presence.

Urine of a male Yellow-bellied Terrapin, which had been kept without food and drink for 49 days. July 9.

Weight of terrapin, May 25th	17,797 grains.
" " July 9th	14,400 "
" lost during forty-five days	3,397 "

Loss of weight each hour, $3\frac{14}{100} = \frac{1}{5667}$th of weight of body.

The bladder had not been emptied during its confinement, and held six fluidrachms of yellow-colored urine, which contained a small, white deposit of the urate of ammonia.

Amount of the urate of ammonia, thirty minims. Sp. gr. of urine, 1019.4.

1000 parts contained—

Water			954.65
Alcohol extract, and urea in small amount	29.26	Solid constituents .	45.35
Uric acid and vesical mucus . .	4.91		
Fixed saline constituents . .	11.18		

The extractive matters were viscid, gummy, of a red color, and exceedingly difficult to evaporate to complete dryness. The uric acid was combined with ammonia and other alkalies. The amount of urea present was very small.

Urine of a Salt-water Terrapin (*Emys terrapin*), which had been kept without food and drink for 40 days. July 23.

Weight of terrapin, June 16th	14,285 grains.
" " July 23d	11,400 "
" lost during thirty-eight days	2,885 "

Loss of weight during each hour, grs. $3\frac{317}{1000} = \frac{1}{4366}$ of original weight.

The bladder contained six fluidrachms of clear, limpid urine, having a decided acid reaction. Sp. gr. 1015. Whole amount of urine excreted during thirty-eight days, about 300 grains.

1000 parts contained—

Water	965.34
Urea and alcohol extract	15.27
Water extract	4.56
Uric acid and vesical mucus	3.27
Soluble fixed saline constituents	8.50
Insoluble fixed saline constituents	3.06

300 grains contained—

	Grains.
Water	289.60
Urea and alcohol extract	4.58
Water extract	1.37
Uric acid and vesical mucus	0.98
Soluble fixed saline constituents	2.55
Insoluble fixed saline constituents	.92
Solid constituents in 300 parts of urine	10.4
" " 1000 " "	34.66

When the alcohol extract was treated with concentrated nitric acid, crystals of the nitrate of urea made their appearance in great numbers. Oxalic acid added to the alcoholic extract, gave a precipitate of the oxalate of urea. Aqua ammonia added to the urine, precipitated stellate crystals of the triple phosphate in considerable numbers. After standing for an hour or two, uric acid was precipitated from the urine, in the form of an orange-colored sediment, which, under the microscope, was composed of lozenge-shaped crystals.

Urine of a Salt-water Terrapin, which had been kept without food and drink for 37 days. Aug. 16.

Weight of terrapin, June 21st	12,280 grains.
" " Aug. 16th	9,255 "
" lost in fifty-six days	3,025 "

Loss of weight hourly, grs. 2.25 = $\frac{1}{5458}$th of original weight.

The bladder contained two fluidrachms of clear yellow urine, having a decidedly acid reaction; also, a considerable quantity of gas. After standing for a short time, a white deposit of the urate of ammonia, and lozenge-shaped and acicular crystals of uric acid settled to the bottom of the vessel.

When the fluid portion of the urine was allowed slowly to evaporate upon a glass slide, under the microscope, numerous crosslets of the chloride of sodium, and stellate, plumose and irregular crystals of the phosphate of soda and fixed alkaline salts gradually made their appearance. When treated with aqua ammonia, numerous delicate, plumose, penniform, and stellate crystals of the triple phosphate were precipitated. When concentrated and treated with nitric acid, crystals of the nitrate of urea made their appearance. The whole amount of urine excreted by the kidneys of this terrapin, in fifty-seven days, 130 grains.

Solid constituents in 130 grains of urine	8.05 grs.

130 grains contained—

Water	121.95
Organic constituents, uric acid, urea, ammonia, &c.	6.45
Fixed saline constituents	1.60
Solid constituents in 1000 parts of urine	61.92

1000 parts contained—

Water	938.08
Organic constituents, uric acid, urea, &c.	49.62
Fixed saline constituents	12.30

We shall now proceed to investigate the effects of a change of diet upon the urine of Chelonians, beginning with the carnivorous.

Urine of a Yellow-bellied Terrapin (*Emys serrata*), which was starved for 30 days, and then transferred to a tub of water, and abundantly supplied with vegetable food (*Portulacca oleracea*) 42 days.

The bladder was distended with five fluidounces of light greenish-yellow limpid urine, neutral to test paper, having a slight smell resembling that of the terrapin.

Amount of urine	2150 grs.
Specific gravity, at 81° F.	999.26
Solid constituents in 2150 grains	5 "

2150 grains contained—

Water	2145
Solid constituents	5

1000 parts contained—

Water	997.7
Solid constituents	2.3

The urine of numerous Yellow-bellied Terrapins (*Emys serrata*), and Salt-water Terrapins (*Emys terrapins*) treated in a similar manner, yielded results similar in all respects.

In every instance the amount of urine excreted by the kidneys was greatly increased, its specific gravity diminished—being often the same as that of pure water—and the reaction was changed from acid to neutral. Hippuric acid was never detected.

The important results of this series of experiments will be given in a table.

We next come to the examination of the urine of herbivorous Chelonians.

Urine of a male Gopher, examined four days after its capture.

The bladder contained five fluidounces of urine, having an odor similar to that of the leaves and grasses in the rectum, and also resembling that of the sheep. Four fluidounces of this was a brownish-yellow fluid. Sp. gr. 1004. The remaining fluidounce was a semi-solid, grayish chalk-like precipitate, having a sp. gr. of 1095.5, and consisting, under the microscope, entirely of minute globules of the urate of ammonia. Urea and hippuric acid could not be detected by microscopical or chemical tests, in either the fluid or semi-solid portion of the urine. Aqua ammonia failed to precipitate the triple phosphate.

1000 parts of the fluid portion of the urine contained—

Water	972.75
Solid constituents	27.25

1000 parts of the semi-solid portion contained—

Water	806.31
Solid constituents	193.67
Amount of semi-solid portion	400 grs.

400 grains contained—

Water	322.52
Solid constituents	77.48

The estimate of the solid parts is below the truth, because some of the ammonia must necessarily have been driven off during the process of drying.

Urine of a Gopher (*Testudo polyphemus*), which was kept without food and drink for 28 days, was as follows:—

Weight of Gopher, June 16th	18,368 grs.
" " July 11th	16,922 "
Loss of weight in 25 days	1,446 "

Loss of weight each hour, $2\frac{41}{100} = \frac{1}{7621}$ of the original weight.

Amount of urine	2 fluidounces.
" of fluid portion	$1\frac{1}{2}$ "
" of semi-solid portion	$\frac{1}{2}$ "
Specific gravity of fluid portion	1008.9

The semi-solid portion was very compact, and composed almost entirely of the urate of ammonia.

Weight of the fluid portion	764 grs.
" " semi-solid portion	236 "
Whole amount of urine	1000 "
Amount of solid constituents, uric acid and urate of ammonia, in 236 grs. of semi-solid matters	$42\frac{7}{10}$
Amount of uric acid in this	37.46

The urate of ammonia must unavoidably have lost some of its ammonia during evaporation.

Amount of solid constituents in 764 grs. of the fluid portion of the urine	21.71
Solid matters in 1000 grains of urine	64.41 grs.

1000 grains contained—

Water	935.59
Urate of ammonia	42.70
Extractive matters, and urea in small amount	15.72
Urates of soda and potassa and mucus	5.99

When the extractive matters were treated with nitric acid, effervescence took place, and crystals of the nitrate of urea made their appearance, under the microscope, in small numbers. Hippuric acid was present in the urine of this animal in small amount. The urine of all Gophers, which I have thus far examined, resembled in all respects that of those just described.

The urine of Chelonians was frequently tested for grape sugar. This substance was absent from the urine of all Chelonians, in a normal condition, except in the case of a Gopher, and its presence in this individual might be accounted for by a suppression of the respiration consequent upon several severe blows upon its head.

Whenever the respiration was suspended, by placing the animals in hydrogen and carbonic acid gases, or by passing a ligature around the windpipe, sugar accumulated in the blood, was eliminated by the kidneys, and appeared in the urine.

The following tables will present a condensed view of all the important results obtained in these investigations :—

Table showing the Loss of Weight, and the Amount of Urine Excreted by Chelonians deprived of Food and Drink.

Name of animal.	Duration of starvation and thirst.	Weight before starvation and thirst.	Weight after starvation and thirst.	Loss of weight during starvation and thirst.	Loss of weight expressed in a fraction of the original weight of animal.	Loss of weight each hour.	Loss of weight each hour, expressed in a fraction of the original weight.	Amount of urine excreted during thirst and starvation.	Amount of urine expressed in a fraction of the original weight.	Amount of urine excreted hourly.	Amount of urine excreted hourly, expressed in a fraction of the original weight of animal.	Amount of solid constituents of urine excreted hourly.
	Days.	Grs.	Grs.	Grs.		Grs.		Grs.		Grs.		Grs.
Emys serrata	14	20,873	18,756	2,117	$\frac{1}{10}$	6.3	$\frac{1}{3313}$	442	$\frac{1}{47}$	1.315	$\frac{1}{15865}$	.0034
Emys serrata	20	34,155	28,675	5,480	$\frac{1}{6}$	11.41	$\frac{1}{2994}$	113	$\frac{1}{302}$	.0235	$\frac{1}{145340}$	.00187
Emys serrata	20	41,086	34,960	6,126	$\frac{1}{7}$	12.76	$\frac{1}{3298}$	741	$\frac{1}{55}$	1.543	$\frac{1}{26627}$	.00611
Emys serrata	26	30,132	22,760	7,372	$\frac{1}{4}$	10.5	$\frac{1}{2870}$	223	$\frac{1}{135}$	0.357	$\frac{1}{846500}$	.00166
Emys serrata	34	38,590	30,142	8,398	$\frac{1}{4}$	10.29	$\frac{1}{3754}$	890	$\frac{1}{44}$	1.09	$\frac{1}{35357}$	.00457
Emys serrata	45	17,797	14,400	3,397	$\frac{1}{5}$	3.14	$\frac{1}{5667}$	300	$\frac{1}{59}$	.0277	$\frac{1}{642130}$	.0012
Emys terrapin	38	14,285	11,400	2,885	$\frac{1}{5}$	3.317	$\frac{1}{4366}$	300	$\frac{1}{47}$	.032	$\frac{1}{446406}$	.00114
Emys terrapin	43	18,832	13,485	5,347	$\frac{1}{3}-\frac{1}{4}$	5.18	$\frac{1}{3635}$	70	$\frac{1}{269}$	.0067	$\frac{1}{2810731}$	
Emys terrapin	56	12,280	9,255	3,025	$\frac{1}{4}$	2.25	$\frac{1}{5458}$	130	$\frac{1}{4}$	.0096	$\frac{1}{1279166}$	.00059

These Chelonians were kept in boxes, and were carefully and frequently examined, and it was found that they never discharged their urine. The amounts, therefore, noted in the table, represent all that was excreted during the period of their confinement.

This table shows the slow waste of the tissues of cold-blooded animals, and the small amount of work performed by their kidneys.

When these animals were deprived of food and drink, the loss of weight was chiefly due to the evaporation from their lungs and skin, and also to the combination of the elements of their fluids and solids with the oxygen of the atmosphere, and their final elimination as carbonic acid gas.

The researches of Winter, Scherer, and Lehmann have shown that a man, for every kilogramme (15,444 grains) of his weight discharges, on an average in the twenty-four hours, about 26 grammes (400 grains) of urine. From these data we may calculate that the amount discharged per hour, for every kilogramme of the weight of a man, equals 16.76 grains. According to this calculation, the amount of urine discharged by a man, hourly, equals $\frac{1}{919}$th the weight of his body. It is probable that, during thirst and starvation, the amount would be much less.

By comparing this with the results which I obtained from cold-blooded animals we see that the amount of urine excreted by a warm-blood animal is from forty to several hundred times more abundant than that excreted by a cold-blooded animal. This is true of all cold-blooded animals.

An Alligator, weighing 76,507 grains, was kept for eighteen days without food and drink, and excreted during this time only two fluidounces of urine.

I have kept Ophidians for two and three weeks, and during this time they voided their urine not more than once or twice, and then in small quantities.

The results of these experiments demonstrate conclusively that, as the solids and fluids of the animal economy are developed, the temperature elevated, and intellect perfected, the compositions, decompositions, and metamorphoses of the organic and inorganic elements become more rapid and abundant.

When we compare the relative size of the kidneys, and the amounts of their excretions in different animals, the question immediately arises: Why should cold-blooded animals, whose circulation is sluggish, which eat but seldom, often abstaining from food for months, whose habits are indolent, and whose excretions and secretions are exceedingly small, be provided with large urinary organs?

In warm-blooded animals it is natural to suppose that an elevated temperature, rapid circulation, and active energetic mode of life, should call for large organs capable of removing in an efficient manner from the blood the products of the disintegrations of the system; but why should we have in a condition of things directly contrary, in every respect, as large organs, to perform the same office in a much feebler degree.

In attempting to explain this phenomenon we must consider the following facts and laws of the animal economy:—

The blood contains a definite amount of materials to be eliminated by the kidneys, diffused throughout its entire mass. That all these materials should be separated, the entire mass of the blood must be presented to the kidneys, and the rapidity of the elimination will depend upon the rapidity of the circulation, and the activity of the excreting cells and the size of the organs.

Temperature also exerts a great influence upon all the actions of the animal economy.

If the temperature of cold or warm-blooded animals be reduced much below the normal standard their functions will gradually become more feeble, and finally cease.

It may be stated, as a general law, that the lower the temperature of any organ the more feeble will be its action.

Nervous force exerts a great influence upon the circulation, and, through it, upon secretion and excretion.

It is known to every naturalist that cold-blooded animals have much less muscular and nervous power in proportion to their size than the warm-blooded ones.

From these considerations, then, it is evident that to perform the same office, to excrete precisely the same amount, larger organs are required in the cold than in the warm-blooded animals.

In Ophidians which have relatively larger kidneys than the other cold-blooded animals, in addition to the reasons stated above, the character of their alimentary canal and their habits render the existence of large kidneys necessary.

These animals are carnivorous and have a short alimentary canal, which, in many instances, is almost completely straight.

They take their food in large quantities, often swallowing animals heavier and larger than themselves. All this animal matter is capable of digestion and absorption into the blood, a large portion of which is superfluous.

The great channel for the elimination of this is through the kidneys; the lungs being mere sacks, and performing the function of respiration in an imperfect manner.

The kidneys, therefore, must be correspondingly large to remove rapidly the large and unnecessary quantities of nutriment which are often received into the circulatory system.

The following table will give a condensed view of the effects of starvation and thirst, and also of a change of diet upon the blood of cold-blooded animals:—

Table Showing the Effects of Starvation and Thirst, and also of a Change of Diet upon the Urine of Chelonians.

Name of Animal.	Length of starvation and thirst.	Specific gravity of urine.	Amount of urine excret'd	Solid constituents of urine excreted.	Water of urine excreted.	Water in 1000 parts of urine.	Solid constituents in 1000 pt's of urine.	Reaction of urine.	Color of urine.
	Days.		Grains.	Grains.	Grains.				
Female *Emys serrata*	17	1011.	442.3	11.33	430.97	974.39	25.61	Acid.	Turbid yellow.
" "	26	1033.5	113.	9.	104.	920.36	79.64	"	Clear yellow precipitate.
" "	29	1020.	223.1	10.396	219.704	947.19	52.81	"	Limpid yellow.
" "	31	1017.5	741.5	29.36	712.14	960.4	39.6	"	Yellow, with precipitate.
" "	38	1017.6	890.6	37.34	853.26	918.08	41.92	"	Yellow, with precipitate.
Male "	49	1019.4	300.	13.02	286.98	954.65	45.35	"	Clear yellow.
Female *Emys terrapin*	40	1015.	300.	10.4	289.6	965.34	34.66	"	Cream-color'd.
" "	43		70.					"	Cream-color'd.
" "	57		130.	8.05	121.95	938.08	61.92	"	Clear yellow.
Female *Emys terrapin*, deprived of food and drink 21 days, and then placed in fresh water and abundantly supplied with vegetable food 28 days. . . .		1002.	840.	3.40	836.60	995.96	4.04	Slightly acid.	Limpid light yellow.
Female *Emys serrata*, deprived of food and drink 30 days, and then supplied with water and vegetable food 42 days. . .		1000.	2150.	5.	2145.	997.67	2.33	Neutral.	Limpid light yellow.
Female *Emys serrata*, deprived of food and drink 30 days, and then supplied with vegetable food and water 60 days. .		1004.	2160.	18.64	2141.36	991.38	8.62	Neutral.	Limpid light yellow.
Female *Emys serrata*, deprived of food and drink 30 days, and then supplied with water and vegetable food 88 days. . .		1000.	2000.	1.	1999.	999.5	.5	Neutral.	Limpid light yellow.
Testudo polyphemus (Gopher). Fluid.		1004.	2000.	54.50	1945.50	972.75	27.25		
Semi-solid.		1095.5	400.	77.48	322.52	806.31	193.67		
Testudo polyphemus (Gopher). Fluid.		1008.9	764.	21.71	742.29	971.59	28.41		
Semi-solid.			236.	42.70	193.30	819.09	180.91		

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